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Reports
Bevins,
C.D.

Forest Fire Densities on the Lobo
National Forest

Coop agreement

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FOREST FIRE DENSITIES ON THE LOLO NATIONAL FOREST

FINAL REPORT

submitted by

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Bruce W. Jeske

to

Fire in Multiple Use Management RD&A Program
Northern Forest Fire Laboratory
Missoula, Montana

in fulfillment of

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0.3 PREFACE

"Forest Fire Density on the Lolo National Forest" is the final report to Supplement Number 2, Master Memorandum of Understanding, dated August 2, 1977, between Systems for Environmental Management, Missoula, Montana, and the Intermountain Forest and Range Experiment Station, Ogden, Utah. The study was conducted under a Cooperative Aid Agreement between Systems for Environmental Management and the Fire in Multiple Use Management RD&A Program, Northern Forest Fire Laboratory, Missoula, Montana, under authority 16 USC 581, 581a - 581i. Systems for Environmental Management is a Montana non-profit research and educational corporation cooperating with land management agencies in the interest of improved environmental management.

0.4 FOREWORD

"Forest Fire Densities on the Lolo National Forest" is structured with four purposes in mind. It is first of all a final report to a cooperative aid agreement between Systems for Environmental Management, a Montana non-profit research and educational corporation, and the Fire in Multiple Use Management RD&A Program, Intermountain Forest and Range Experiment Station, USDA Forest Service. The problem statement, study objectives, and study design are briefly discussed in Section 1. Section 2 covers the procedures and results of each individual task identified in the study plan. Second, the report describes an accurate and expedient methodology for computation of forest fire densities on Northern Region national forests (Section 3.1). Third, it is a finding of fact on lightning and man-caused forest fire occurrence densities on the Lolo National Forest from 1955 through 1974. Sections 3.2 through 3.5 report the effects of ignition source, cover type, stand management status, elevation, aspect, slope, and season of the year on forest fire density. Conclusions and a summary are presented in Section 4. Finally, the body of the report contains tables of forest acreage estimates, fire occurrence data, and forest fire occurrence densities by stratification class for use in long range fire planning and occurrence simulation.

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1.0 INTRODUCTION

1.1 PROBLEM STATEMENT

Forest fire occurrence records have been maintained by the USDA Forest Service since passage of the Weeks Law of 1911. Fire occurrence records are usually collated and summarized annually at successively higher administrative levels within the Forest Service. The summaries permit fire managers and planners a cursory look at fire load distribution by ignition cause, cover type, fuel type, elevation, aspect, slope, season of the year, and other summary stratifications.

A weakness in the fire occurrence data has been the inability to express fire incidence as a density measure. Fire density computation requires the normalization of fire starts/year within some stand or site class to starts/year/unit area of the class type. The information content and utility of the fire summaries would be greatly enhanced through such a normalization procedure. Specifically, direct comparisons of fire occurrence may be made between different cover types, elevation belts, aspects, slope classes, and stand management status classes, for example. To illustrate, the Lolo National Forest has had 136 lightning fires in western larch stands and 352 lightning fires in Douglas-fir stands from 1955 to 1974, inclusive. This may not necessarily mean that Douglas-fir cover types are more fire-prone than western larch, however, because the acreages for each type are unknown. If western larch types have one-third the area as Douglas-fir, then western larch would actually have a higher fire density.

To determine fire occurrence densities it is necessary to merge the historical fire occurrence records with yearly stand and forest inventory data on the number of acres existing within each stand and site stratification class. A major problem to be addressed is whether or not accurate and adequately resolved forest inventory records exist for this purpose.

1.2 STUDY OBJECTIVES

The three objectives of the study were to:

1) establish and document a methodology of locating, assembling, and analyzing forest fire occurrence, forest inventory, stand examination, and other appropriate data bases for constructing fire density tables for Northern Region national forests,

2) to produce a document quantifying the empirical relationships between historical forest fire occurrence by cause category and related forest and site characteristics, and

3) to demonstrate the data collection and analysis techniques by producing prototype strategic and tactical fire occurrence density tables for all federally-administered lands within the Lolo National Forest. A strategic level fire density table implies fire densities summarized on an annual basis. Tactical level summaries reflect seasonal variations in fire occurrence patterns throughout the year.

The overall purpose of the study was to establish a feasible methodology of converting raw forest fire occurrence data into fire density information utilizing data and resources generally available to Northern Region national forests. The conversion from fire occurrence to fire density requires an estimation of acreages existing within some stratification scheme for each year on record. The basic stand and site stratifications used by the study are dominant forest cover type, site elevation, slope, and aspect, and stand management status or condition -- standing timber, harvested/undisposed, and harvested/disposed stands.

1.3 STUDY DESIGN

There were two distinct phases to the study. The first was an investigation into the feasibility of converting forest fire occurrence data into fire density information. Individual Fire Reports (5100-29 and 929 forms) are maintained by the USDA Forest Service for each reported fire, and readily provide the necessary fire occurrence data. The central problem addressed by the first part of the study is the development of an accurate, low cost method of determining the yearly distribution of forest acres among the same stand and site classifications as used in the fire reports. The classifications of primary importance are site characteristics of elevation, slope, and aspect, and stand characteristics of cover type and management status. The study assumed the acreage distribution for cover type, elevation, slope, and aspect to remain constant from one year to the next. The number of acres by management status, on the other hand, were permitted to change between years as different stands were harvested, regenerated, or underwent some form of site preparation or hazard reduction.

The second portion of the study addressed itself to an evaluation of management activities with respect to fire density. How does hazard reduction or site preparation affect the number of lightning and man-caused fire starts per million acres per year? How does timber harvesting affect the probability of a fire starting within a stand? The study includes an identification of fire-prone cover types, elevation belts, and aspect and slope classes for the Lolo National Forest. Finally, an attempt has been made to explain variability in fire density due to inherent stand and site characteristics.

2.0 STUDY TASKS

2.1 TASK 1

"Determine the availability and suitability of extant data bases for construction of strategic and tactical fire occurrence density tables for the Lolo National Forest."

Task 1 consisted of identifying and evaluating those data bases that most readily provide the information required to compute fire density estimates. The density computation requires a source of fire occurrence data and sources of acreage distribution estimates. The data bases selected must be capable of integration with one another, preferably via computer, and able to be cross-referenced by cover type, management status, elevation, slope, and aspect.

2.1.1 Forest Fire Occurrence Data

Every reported forest fire occurring in, or spreading to, USDA Forest Service fire protection boundaries is recorded on an Individual Fire Report, form 5100-29 (formerly 929 form). Information on each report includes the date, time, and location of the fire, cover type, stand condition, and fuels prevailing in the stand, site information such as elevation, slope, aspect, and topography, fire behavior and size estimates, and a record of the suppression effort required. The forms and their content are usually standardized within each decade, but differ in information content and codes from one decade to the next. The forms are originally filled out in longhand by the recorder and later converted to the ADP code system in use for that decade. Generally speaking, the 5100-29 forms for the Lolo National Forest were found to be completely filled out, and only a few missing data entries were detected.

Three sources of the fire occurrence data are readily available to Northern Region national forests. The first source is the original 5100-29 forms. A complete set is maintained at the Northern Region headquarters and each forest retains a set in its files. The Northern Region also maintains a magnetic computer tape on the CDC 3100 containing the encoded 5100-29 data. A similar tape has been created by Colorado State University¹ for the Fire Meteorology Research Work Unit, Northern Forest Fire Laboratory. It differs from the Region One tape in that some reconciliation has been made between the four different fire report forms used since 1940. While the latter two sources have the distinct advantage of being in machine-readable form, several problems prevent their use for the current study.

First, the magnetic tape versions contain only the encoded fire occurrence data, resulting in a substantial loss of data integrity and information content. The most important loss is in elevation data. Rather than recording the actual fire elevation in feet m.s.l., a coding system was used that changed from the 1960's to the 1970's. This would normally cause little problem except that the elevation classification scheme also changed between decades. Before the 1970's, elevation was coded by one-thousand foot belts beginning at 1000 feet m.s.l. In 1970, however, a split system was started with bands of 1000-1500 feet, 1501-2500 feet, 2501-3500 feet, and so on in even thousand foot intervals. It therefore is not possible to reconcile the 1970's classification codes with earlier elevation codes. A similar problem arose with slope classes, which were coded in 10% slope increments in the 50's and 70's, but in 20% intervals in the 60's.

A second problem in using the magnetic tape versions is the absence of land ownership identification. This is important since acreage estimates are generally available only for federally-owned lands within forest fire protec-

tion boundaries, and many fires start on private inholdings. From 1955 to 1974, inclusive, 31.8% of all reported lightning fires, and 61.4% of all man-caused fires within the Lolo National Forest fire protection boundaries started on private lands. The fires were excluded from the computation of forest fire densities since no corresponding acreage estimates for private lands are available.

Due to the two major problems of loss of data integrity and absence of land ownership identification, it was necessary to return to the original 5100-29 reports as the fire occurrence data base. Even then, certain problems arose, primarily from the decade changeovers in coding systems and information content. For example, detailed information on the fuel complex in which the fire started exists only on the 50's reports. Data on slope position (bottomlands, hillsides, ridgetops, etc.) were recorded only during the sixties, and cover type/management status codes have changed every decade. Analysis of fire densities by fuel treatment class or slope position is therefore restricted to a ten year period, and such analysis was not attempted by the study. Problems also arose from the use of zero ("0") as a code numeral. Use of zero codes made it difficult to distinguish between a true zero entry and a blank entry.

2.1.2 Acreage Estimation by Cover Type, Elevation, Slope, and Aspect

Two primary sources of data on acreage distribution by cover type, elevation, aspect, and slope were examined. The first is the ten year timber management plan, and the second the Forest Inventory/Stand Examination data base. The study assumed acreage distributions between classes of cover type, elevation, slope, and aspect to remain constant or change insignificantly on the Lolo National Forest from 1955 through 1974.

The ten year timber management plans are prepared by the forests' working circles and vary in information content, format, and reporting dates. The data base is difficult to work with because it is dispersed, dates and sources of inventory information are not well documented, error estimation is not possible, and cross-stratification cannot be made, for example, between cover type and management status.

The Forest Inventory/Stand Examination data base provides a much better source for acreage estimation. The inventoried stands included in the data base were selected for sampling with probability proportional to size after Stage and Alley². The sampling method was designed specifically for estimation of forest-wide totals and averages from sampled plots and stands. The base includes a wide range of information on stand and site characteristics including cover type, stand condition, elevation, aspect, and slope. Cross-stratification is possible between any sets of characteristics. The data are available in two machine-readable formats. The first is the FINSYS Data Summary Cards, and the second is the FINSYS TABLES and OUTPUT computer software package.

The FINSYS Summary Cards contain stand and site characteristics as averaged over all sample plots within the stand. Each stand has three cards of information. The card decks are maintained by the Northern Region and reside on CDC 3100 magnetic tape storage. Since the cards contain data already averaged over the stand, they yield slightly different forest-wide totals than do the FINSYS TABLES and OUTPUT routines which use the original plot by plot data. Use of the Summary Cards therefore results in the loss of some data information accuracy. Another problem with using the Summary Cards is the lack of a statistically acceptable means of deriving variance estimates of acreage distributions from stand averaged data.

Unlike the FINSYS Summary Cards, the TABLES and OUTPUT programs provide a complete software system for manipulating the large Forest Inventory/Stand Examination data base for Region One national forests. Cross-stratification between any two or three stand/site characteristics and variance estimation of forest-wide totals and averages are standard features of the package. The FINSYS system is national in scope and resides at the USDA Forest Service's Fort Collins Computer Center. Although it is quite expensive to use, the accuracy of the data output, wealth of stand and site information available, ease of cross-stratification between data elements, availability of variance estimates, and flexibility of use make it the preferable method of obtaining national forest acreages.

Some minor idiosyncracies do exist in the Forest Inventory/Stand Examination data base. Some forests were more conscientious in completing the data forms than others, and it is possible to have large portions of the forest's land area in an "uncoded" class. It also makes use of zero codes, making it difficult to distinguish between coded and uncoded data elements.

The land base from which inventoried stands were selected may also vary between national forests. On the Lolo National Forest, potential sample areas were selected only from federally-owned, non-wilderness lands, and it was necessary to exclude those fires starting on private or wilderness lands during computation of fire densities for the Lolo.

Finally, the Forest Inventory/Stand Examination data base is not suitable for determining the yearly acreage distribution among stand management status classes since it was a one-time inventory only. Even for 1974, the year of the Lolo inventory, acreage estimates for harvested/undisposed and harvested/disposed sites often have standard errors in excess of the mean just because they constitute such a small fraction of the total forest area.

2.1.3 Acreage Estimation by Management Status Class

The stand condition or management status class reflects the timber management phase of the stand. The classes recognized by the study are standing, stocked timber, harvested/undisposed stands, and harvested stands that have received some form of hazard reduction and/or site preparation. The Stand Examination and Management Status Record (Form R1-2410-17) contains the management history of all stands on the forest that have undergone some form of management activity. The record includes information on cover type, elevation, slope, aspect, and dates and methods of harvest, hazard reduction, site preparation, and/or regeneration. The master record is maintained on magnetic tape storage on the Northern Region's CDC 3100 computer and provides a suitable and accessible method of determining the number of acres existing in each management status class each year. One complication with using the data base is the high incidence of incomplete record entries. About 9% of the stand records on the Lolo National Forest are uncoded by cover type. Oftentimes the only data entry on a stand record is the harvest date.

2.1.4 Data Base Integration

The three most suitable data bases available to Northern Region national forests for computing forest fire occurrence densities are:

- 1) the original, uncoded Individual Fire Reports (5100-29 forms),
- 2) the Forest Inventory/Stand Examination data base as accessed by the FINSYS TABLES and OUTPUT programs, and
- 3) the Stand Examination and Management Status Record stored on Northern Region magnetic tape.

The Individual Fire Reports provide the necessary forest fire occurrence data by cause category, cover type, management status, elevation, slope, and aspect. The FINSYS TABLES and OUTPUT programs provide the acreage distributions between classes of cover type, elevation, slope, and aspect. The yearly estimates of acreages within the management status classes are provided by the Stand Examination and Management Status Record. The five major stratifications of cover type, management status, elevation, slope, and aspect are all fairly compatible between the three separate data bases, and differences can be reconciled. Furthermore, all three data bases are already in, or easily converted to, ADP formats.

2.2 TASK 2

"Estimate the number of acres on the Lolo National Forest according to a developed stratification and classification scheme."

2.2.1 Stratification Classes

A stratification classification scheme was developed for the stand and site characteristics of cover type, management status, elevation, slope, and aspect which conformed to three major criteria. First, classes within each stratification must be wide enough to have at least several fire starts occurring within them over the twenty year period examined. Second, the acreage estimates for the classes should have an acceptable level of error. Third, data elements and codes from the three separate data bases must be capable of reconciliation into the developed classification scheme.

Nine major cover types were identified as capable of cross-reference between the three data sets; ponderosa pine, Douglas-fir, lodgepole pine, spruce, western larch, grand fir, western white pine, western red cedar/western hemlock, and subalpine forest types (subalpine fir, whitebark pine, limber pine, and fir-spruce). No inventoried acreages were found for hardwoods, other conifer species, grasslands, or shrubfields on the Lolo National Forest inventory. The stand cover type for all three data sets was based upon the most common species present. Error estimates of cover type acreages ranged from a low of 6.4% of the mean for Douglas-fir and lodgepole pine, the two most common types on the Lolo, to a high of 68.4% standard error for western white pine, the least common type.

Management status classes originally selected were seedling/sapling, poletimber, sawtimber, harvested/undisposed, and harvested/disposed stand conditions. Stand management status is indicated on both the fire reports

and the Stand Examination and Management Status record. The original five classes were reduced to three -- standing timber, harvested/undisposed, and harvested/disposed -- because the Forest Inventory/Stand Examination data base for the Lolo National Forest projected no acreages in the seedling/sapling or poletimber stages for some cover types even though forest fires had been reported in those stages and cover types on the individual fire reports.

Nine aspect classes were selected, eight corresponding to the major 45 degree compass points and one for level sites. Standard errors of acreage estimates ranged from 11% to 18% for the eight aspects, and was 23% for level acreages. Combining the eight aspects into four groups corresponding to the cardinal compass points reduced the standard errors to around 10%. All three data bases used the same coding system for aspect.

Five elevation bands were selected, generally of one-thousand foot intervals -- less than 4000 feet m.s.l., 4000-4999, 5000-5999, 6000-6999, and 7000 feet or greater. Errors ranged from 6% for the 5000-5999 foot band, the largest in terms of acreage, to 25% for the 7000 foot and greater band, which had the smallest area. Both the Forest Inventory/Stand Examination (FI/SE) and Stand Examination and Management Status (SEMS) data bases recorded elevation to the nearest 100 feet. Fire start elevations were taken directly from the uncoded 5100-29 forms.

Nine slope classes were used as per the FI/SE and SEMS coding systems; 0-15%, 16-25%, 26-35%, 36-45%, 46-55%, 56-65%, 66-75%, 76-85%, and greater than 85% slope. Slope was generally recorded to the nearest 5% on the fire reports. Error estimates of slope class acreages were under 20% of the mean for the first seven classes, and exceeded 50% on the two steeper classes.

2.2.2 Acreages by Cover Type, Elevation, Aspect, and Slope

The FINSYS TABLES and OUTPUT programs were used to compute acreage distributions among classes of cover type, elevation, aspect, and slope. The FINSYS software permits the user to group stand and site characteristics into any classes desired. Output consists of tables of total acreages stratified simultaneously by two stand or site characteristics. Documentation of the two programs is on file at the Northern Region's timber management office. A single computer run to get all the above acreage and variance estimates for the Lolo National Forest costs about \$50. The FINSYS data base for the Lolo contains 583 stands from thirty sample locations. The acreage estimates and their standard errors for the Lolo National Forest are given in the tables in Section 3.

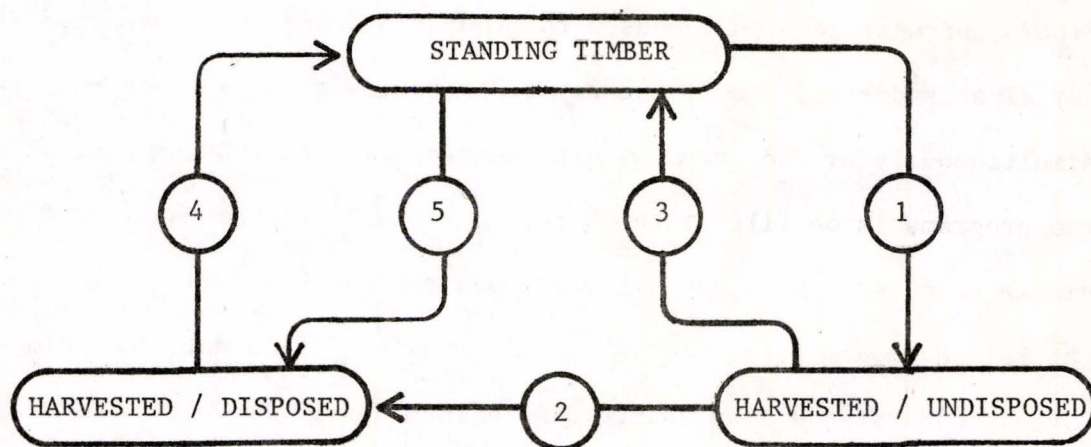
2.2.3 Annual Acreages by Management Status

The Northern Region's magnetic tape of SEMS records was accessed to model yearly acreage distributions among the three stand management status classes. The entire master tape was copied onto a Lawrence Berkeley Laboratory CDC 7600 magnetic tape for use in the study. The Lolo National Forest's portion of the tape contained 10,753 stand records at the time it was copied.

A forest management model was designed to facilitate reconstruction of annual acreage distributions by management status (Figure 2.1). Stand areas were transferred between the three status classes via five possible pathways:

- 1) Standing timber acres were converted to harvested/undisposed acres whenever a stand was harvested. Harvest methods included clearcut, shelterwood, seed tree, overstory removal, rehabilitation, select, salvage, and intermediate cuts. Excluded were stand release, precommercial and commercial

FIGURE 2.1
FOREST MANAGEMENT STATUS CYCLE



VECTOR	DESCRIPTION
1	Harvest -- clearcut, shelterwood, seed tree, overstory removal, rehabilitation, select, salvage, and intermediate cuts
2	Hazard Reduction or Site Preparation -- prescribed burning, logging, jackpot burning, dozer piling and terracing, hand piling, trampling, herbicide spraying, spraying and burning, rolling chopper, machine scarifying, furrowing, and discing, and wildfire
3	Regeneration without Previous Hazard Reduction or Site Preparation
4	Regeneration Following Hazard Reduction or Site Preparation
5	Wildfire -- severe and large enough to be coded as a "harvest or other drain" on the Stand Examination and Management Status record

thinning, and pruning. The distinction between what did and did not constitute a harvest corresponded to the "mature uncut" and "mature cut" categories used on the 1960 and 1970 fire reports.

- 2) Harvested/undisposed acres were converted to harvested/disposed acres whenever any form of hazard reduction or site preparation were applied to a stand. Hazard reduction methods included prescribed burning, lopping, jackpot burning, dozer piling and terracing, hand piling, and trampling. Site preparation methods were prescribed burning, herbicide spraying, spraying and burning, machine scarifying, terracing, furrowing, and discing, rolling chopper, and wildfire. About 40% of all hazard reductions and site preparations on the Lolo National Forest were by some form of machine treatment, and another 40% by some burning treatment. About 10% of the treated area was by hand piling. All hazard reduction and site preparation methods were grouped together in the forest management model because most decades of the fire report forms do not distinguish between disposal methods used at the fire site.
- 3) Harvested/undisposed acres were transferred to standing timber acres whenever the area was regenerated without previous hazard reduction or site preparation.
- 4) Harvested/disposed acres were converted to standing timber acres whenever the area was regenerated following hazard reduction or site preparation.

- 5) Standing timber acres were converted to harvested/disposed acres whenever a wildfire occurred which was large enough to be coded as a "harvest or other drain" on the SEMS record. The site was not considered to return to standing timber unless a post-fire regeneration date was coded on the stand's record.

A computer program, FINLEV1, was written to determine the number of acres passing between the three management status classes via the five vectors by year and each of the nine cover types. The 1974 FI/SE inventory totals by cover type for the Lolo National Forest served as the starting point from which yearly acreage distributions by management status class were reconstructed back through 1955.

2.3 TASK 3

"Estimate the distribution of acres on the wilderness portions of the Lolo National Forest by the developed stratification scheme."

Data on the stratified acreages within wilderness areas of the Lolo National Forest are required if wilderness fires are to be included in the fire occurrence density tables. The approach followed was to estimate acreage by thousand-foot elevation band from 7½" topographic maps of the Lolo portions of the Selway-Bitterroot and Scapegoat wilderness areas. Acres by cover type, slope, and aspect were then determined from their proportional distribution among the same elevation bands in the non-wilderness portions of the forest.

The above procedure is not recommended for fire density estimation for several reasons. First, the method probably has a high (but unknown) degree of error associated with it. Second, it required two man-weeks to perform the task for the 82,000 wilderness acres in the Lolo National Forest. And third, only 26 of 1948 fires (1.3%) occurred on wilderness lands within the Lolo from 1955 through 1974. Wilderness acres and wilderness fires were therefore excluded from subsequent analysis of Lolo National Forest fire densities.

2,4 TASK 4

"Determine the number of forest fires occurring within the Lolo National Forest from 1955 to 1974, inclusive, by the developed stratification scheme."

The original longhand versions of the individual fire reports were used to determine forest fire occurrence on the Lolo National Forest. Information was transferred onto coding sheets, keypunched, and stored on magnetic tape for later use by computer programs. Information recorded from the fire reports included individual fire number, forest and ranger district, date of ignition, general and specific cause of the fire, the elevation, slope, aspect, cover type, and management status at the point of origin, the fire size class, acres burned, township, range, section number, and ownership at the point of ignition.

The individual fire number, date, elevation, slope, acres burned, and location were transferred directly using uncoded data values. Standard Forest Service codes used by the FI/SE and SEMS were followed for coding forest, ranger district, aspect, and fire size class. New coding systems were developed which were consistent between all decades of the fire reports and the developed classification scheme for general and specific cause, cover type, management status, and ownership. No zero codes were used. The fire occurrence tape format and codes are documented in Appendix A.

Once the data were transferred onto magnetic tape, the tape was sorted by township, range, and section number, and those fires occurring within wilderness boundaries were identified. A wilderness/non-wilderness code was then added to each fire's data record on the tape.

2.5 TASK 5

"Create tables of lightning fire occurrence densities from 1955 to 1974, inclusive, on the Lolo National Forest by the developed stratification scheme."

2.5.1 Lightning Fire Densities by Cover Type, Elevation, Slope, and Aspect

PROGRAM LEVEL01 was written to read acreage estimates from data card input, read the number of fires by stratification class from the fire data tape, and compute the lightning fire occurrence densities for each year by cover type, elevation, aspect, and slope. The computed lightning fire densities were then passed to standard Statistical Packages for the Social Sciences (SPSS)³ software routines for statistical analysis.

2.5.2 Lightning Fire Densities by Cover Type and Management Status

PROGRAM FINLEV1 was written to read the SEMS records from magnetic tape, determine the yearly acreage distribution by cover type and management status class, read the fire data tape for the number of lightning fires by cover type and management status class, and compute the corresponding fire densities. The resulting lightning fire density values were then passed to standard SPSS statistical analysis routines.

2.6 TASK 6

"Perform statistical analysis of lightning fire occurrence densities from 1955 to 1974, inclusive, on the Lolo National Forest."

Chi-square, homogeneity of variance, and analysis of variance statistics were computed on the twenty annual repetitions of lightning fire occurrence densities to test for possible effects of cover type, management status, elevation, aspect, and slope on the number of starts per million acres per year. After initial testing, some classes within a stratification were combined and new statistics computed. Classes were grouped by similarity of their fire density values, producing fewer and more distinct classes. Such groupings also increased the number of acres within groups, and to some degree decreased their standard errors.

2.7 TASK 7

"Collect data relating to man-caused forest fire occurrence on the Lolo National Forest from 1955 to 1974, inclusive, and determine man-caused fire densities."

Man-caused forest fires were divided into five man-caused categories. The categories were defined on the basis of the type of activity, and not the firebrand, that caused the fire. Forest management fires result from timber harvesting and related forest and range management practices. The category would include exhaust sparks or smoking fires, for example, as long as they were connected with forest management activities. A second category, industrial fires, are those associated with railroads, highways, and powerline right-of-ways. Recreational fires include fires by hikers, campers, hunters, fishermen, berry pickers, or any other cause associated with recreational activities. The incendiary/children category reflects an intention by some person to start a fire or firebrand. The fifth category contains miscellaneous and other man-caused fires.

Acreage estimates made for the lightning fire density computations were also used to determine man-caused densities by cover type, management status, elevation, aspect, and slope. Fire occurrence data were taken from the fire report magnetic tape created in Task 4.

2.8 TASK 8

"Perform statistical analysis of man-caused fire densities on the Lolo National Forest from 1955 to 1974, inclusive."

Yearly man-caused fire density estimates for the five cause categories were passed to SPSS statistical routines for analysis. Chi-square and analysis of variance statistics were applied as tests of possible effects of cover type, management status, elevation, aspect, and slope on fire density for each cause category.

2.9 TASK 9

"Produce tables of strategic and tactical fire occurrence densities of lightning and man-caused forest fires on the Lolo National Forest from 1955 to 1974, inclusive."

Strategic level fire density tables of lightning and man-caused forest fires by cover type, management status, elevation, slope, and aspect were produced as a result of Tasks 1-8. Strategic fire density tables are presented in Section 3.2 for lightning fires, and Section 3.4 for man-caused fires.

Computer programs were written to further stratify fire densities by month and semi-monthly periods. The resulting tactical level fire density tables are presented in Section 3.3 for lightning fires and Section 3.5 for man-caused fires, and reflect the possible seasonal effects on fire occurrence densities on the Lolo National Forest.

3.0 STUDY RESULTS AND DISCUSSION

3.1

RECOMMENDED METHODOLOGY FOR COMPUTING FOREST FIRE DENSITIES

The following procedure is recommended as the most accurate and expedient in terms of information derived on historical forest fire occurrence densities in Northern Region national forests.

3.1.1 Step 1 -- Problem Design and Data Stratification

Select a suitable stratification and classification scheme for the problem being addressed. Is the problem one of identifying fire-prone stands and sites, or is it to evaluate the effects of hazard reduction or site preparation on fire occurrence? A selection must be made as to both the type of fires to be included in the study and the stand and site characteristics among which the fires will be stratified. Whatever stratification used, the data elements selected must be present on both the individual fire reports and the Forest Inventory/Stand Examination FINSYS data base. Data values and codes used for a particular stand or site characteristic must be reconciled between the data bases and decades of fire report forms to be used. If a stratification is to be based on management status, all data elements and codes must also be present and reconcileable with the Stand Examination and Management Status Record (FSH R1-2410-17).

A maximum of about ten classes is recommended within a stratification. Classes with a small proportion of the forest's total acreage within them are undesirable for two reasons. First, the standard error of the acreage estimate for a particular class is inversely related to the fraction of the forest's total acreage within the class. Second, the chance occurrence of a single fire within a class of very small area will have a greater effect on

the mean and variance of the resulting fire density than for a class with larger area. Use of classes with less than 5% of the forest's total acreage should be avoided when possible.

Select a suitable time period to be examined. A minimum of fifteen years of fire occurrence records, preferably beginning in the 1960's, is recommended to ameliorate the effects of very high and very low fire years. If a management activity stratification is used, keep in mind that it is difficult to use much of the Stand Examination and Management Status record prior to 1960 because of a high percentage of incomplete stand history records for some forests. Some of the fire report ambiguities between decades are also resolved by using only 1960's and 1970's forms since the data elements and codes are most alike between the two. It may become necessary to use the 1950's data to answer some specific questions. For example, if the study is to examine the effects of slash aging and treatment methods on reported fire densities, the analysis would necessarily be restricted to the 1950's reports since they are unique in containing that type of fuels information about the fire occurrence site.

3.1.2 Step 2 -- Construction of a Fire Occurrence Data Tape

Transfer the required data elements from the original 5100-29 Individual Fire Reports to coding sheets, one line of data per fire. Recommended data elements include the individual fire number, forest and district identification, general and specific cause codes, cover type, management condition, fuels present, elevation, aspect, slope, topography, township, range, section number, and ownership code. Include other data elements as identified in Step 1. Formats and codes used in the present study are documented in Appendix A. When coding continuous variables such as elevation, slope, and acres burned, it is best to record the actual data value rather than some arbitrary

numerical code in the interest of maintaining data integrity. Avoid using zero codes.

Key punch the coded data sheets and transfer the card deck onto magnetic tape storage for later access by computer programs. Sort and print out all the fire records by township, range, and section number. Determine whether or not each fire started within wilderness area boundaries and add a wilderness/non-wilderness code to the fire's magnetic tape record.

3.1.3 Step 3 -- Determine Non-dynamic Acreages for Stratification Classes

The FINSYS TABLES and OUTPUT software package is recommended to compute acreages for those stand and site characteristics which do not change area distributions significantly from one year to the next. Such characteristics include cover type, elevation, aspect, slope, fuels, topography, and slope position. The FINSYS software system is available on the Fort Collins Computer Center UNIVAC 1100 facility, and supporting documentation is on file at the Northern Region's timber management office. The package accesses the Forest Inventory/Stand Examination data base for the national forest specified and prints tables of acreage totals and standard errors for the stratification and classes selected by the user. Output tables are usually crossed between two stratification characteristics (such as cover type and aspect). If acreages for some classes are too small and have unacceptable errors, group them with neighboring classes.

Key punch acreage estimates from the FINSYS OUTPUT tables onto computer data cards. Each stratification should have its own data deck containing one card per class. Card format used in the present study was / A10, F10.1 / , permitting a ten-character alphanumeric identifier to precede the acreage value.

3.1.4 Step 4 -- Determine Dynamic Acreages for Stratification Classes

This step is necessary only if the study is to address the effects of management activity or stand condition on forest fire densities. The number of acres within a management status class may change from one year to the next as a result of forest management practices on one or more stands within the forest. A computer program, FINLEV1, was written for use in the present study to compute yearly acreages by cover type and stand management status.

Transfer the Stand Examination and Management Status Record for the national forest onto magnetic computer tape. The master record for all forests is on file on the Northern Region's CDC 3100. It is advisable to transfer just the one forest's management records as some forests have over 20,000 records on file, making it quite expensive to read and reread the entire tape.

The next step is to develop a dynamic model which shows the management status classes defined by the study in Step 1 and the possible pathways by which acreages may be exchanged between the classes each year. The direction and rules for using the pathways must be defined. A forest management cycle as modeled for use in the present study is shown in Figure 2.1.

The final task is to write a computer program, or adapt the FINLEV1 program used in the present study, to use the forest management cycle to model the yearly acreages by management status class. The card deck for cover type acreages created in Step 3 is used for beginning acre estimates for the year of the Forest Inventory/Stand Examination. The Stand Exam and Management Status tape created above is then used to backdate and distribute the forest's acres among the management status classes at yearly increments.

3.1.5 Step 5 -- Determine the Forest Fire Density for Stratification Classes

For non-dynamic stand and site stratifications, the card decks produced in Step 3 are used along with the fire data tape created in Step 2 to compute yearly forest fire density values. A computer program, LEVEL01, was written for this purpose in the present study. The program reads the fire data for the appropriate years and cause categories and assigns each fire to a class within each stratification. The fire occurrence by class for each year is then normalized by the millions of acres in the class. An additional routine may be written to compute the mean and variance of the fire densities for each class, although the present study passed all density values by class and year to SPSS statistical routines for analysis.

For stratifications with dynamic acreage classes, the FINLEV1 program used in Step 4 may be adapted to determine forest fire occurrence densities. The program reads the fire data tape for the appropriate years and cause categories and assigns each fire to a cover type and management status class. The fire occurrence within a class for each year was then normalized by the millions of acres existing in the class for the same year. Again, an additional routine may be added to FINLEV1 to compute the mean and variance of the forest fire densities over the years examined, or the values may be passed to SPSS or similar standardized software routines for statistical analysis.

Complete documentation of programs LEVEL01 and FINLEV1 are available upon request from Systems for Environmental Management, Missoula, Montana.

3.1.6 Step 6 -- Analysis and Interpretation of Forest Fire Densities

The normalized forest fire density values (reported fire starts/million acres/year) facilitate direct comparison of fire incidence between classes of stand and site characteristics. Fire density is especially valuable in ranking the relative order of stands and sites and identifying fire-prone areas. This is not possible with fire occurrence data alone.

The forest fire density tables computed have limited value in predicting or modeling forest fire occurrence, especially over periods shorter than five or ten years. The standard deviation about the mean densities tends to be high, reflecting the variability between high and low fire years. Variance is higher for those stands and sites with higher densities. High fire density areas are more responsive to the type of fire year than are low fire density areas, resulting in broader confidence intervals for those classes of greatest interest.

Keep in mind that the fire occurrence data base used to compute forest fire densities contains only those fires which, for some reason, were reported to the USDA Forest Service. While this may cause the data base to be somewhat biased to begin with, it may be argued that most uses of the fire density tables will be concerned specifically with only those fires that are reportable.

When looking for underlying explanations of the variability between classes of forest fire densities, it is important to keep in mind the two separate components which contribute to a fire being reported. The first component is the presence of a firebrand, and the second is the presence of fuel beds which will support the fire until it is detected. Variations in forest fire occurrence densities may be attributed to one or both of the components. The high fire density on ponderosa pine stands on the Lolo Nation

al Forest, for example, may be more readily attributed to the grass and litter fuels complex commonly found in this type than to some inherent attraction of lightning or other firebrands by ponderosa pine.

3.2 STRATEGIC LIGHTNING FIRE DENSITIES

3.2.1 Cover Type Effects

A total of 1513 lightning fires were reported on federally-owned lands within the Lolo National Forest fire protection boundaries from 1955 to 1974, inclusive. Of these, 1454 started within one of the nine cover types studied (Table 3.1). Ponderosa pine had the highest number of reported lightning fires with 489, followed by Douglas-fir with 352. Western white pine had the fewest lightning fires with 6. Douglas-fir was the most common cover type on the Lolo, covering 708,625 acres, and western white pine was the least common, covering 2,197 acres. Total area of stocked or stockable timberlands for the nine cover types was 1,814,646 acres, or 91.7% of the total area of the Lolo National Forest.

Significant differences in mean lightning fire densities were found between the nine cover types for the twenty year period. The group with the highest lightning fire density consisted only of ponderosa pine with 470 starts per million acres per year. Western larch, spruce, and western white pine constitute the second group with lightning fire densities ranging from 136 to 167 ignitions/mm acres/year. The third cover type group included cedar/hemlock, grand fir, Douglas-fir, lodgepole pine, and subalpine species (subalpine fire, spruce-fir, whitebark pine, and limber pine). Lightning fire densities for the third group ranged from a high of 33 starts/mm acres/year for cedar/hemlock to a low of 17 in subalpine types. The usefulness of fire density in ranking the fire risk of stands is well demonstrated in comparing Douglas-fir with western white pine. Although Douglas-fir had the second greatest number of lightning fires reported, and western white pine had the least, lightning fire density for white pine is over five times that of Douglas-fir.

TABLE 3.1

LIGHTNING FIRE DENSITY BY COVER TYPE
LOLO NATIONAL FOREST: 1955 - 1974

(Fires/mm acres/year)

SPECIES	LEVEL 1	LEVEL 2	NET AVERAGE
Ponderosa Pine	469.8 (9.8%) 489 52041.5 (23.9%)	469.8 (9.8%) 489 52041.5 (23.9%)	
Western Larch	166.9 (18.2%) 136 40742.8 (27.6%)		
Spruce	147.9 (25.0%) 55 18599.0 (35.2%)	160.1 (17.0%) 197 61538.3 (20.9%)	
Western White Pine	136.6 (54.6%) 6 2196.5 (68.4%)		
Cedar - Hemlock	32.9 (21.0%) 14 21272.7 (40.5%)		40.1 (9.1%) 1454 1814645.9 (0.0%)
Grand Fir	24.9 (19.6%) 47 94460.3 (24.3%)		
Douglas-fir	24.8 (14.1%) 352 708624.7 (6.4%)		
Lodgepole Pine	23.0 (19.3%) 227 492904.4 (6.4%)	22.6 (15.4%) 768 1701066.1 (1.1%)	
Subalpine Types	16.7 (20.0%) 128 383804.0 (10.4%)		

FIRE DENSITY (%SE)
FIRE NUMBER
COVER ACRES (%SE)

Chi-square tests showed cover type to have a highly significant effect on the Lolo National Forest lightning fire densities. In fact, yearly lightning fire densities by cover type had highly significant nonhomogeneity of variance, precluding normal statistical tests such as analysis of variance. The nonhomogeneity of density variance persisted even after several transformations of the data were attempted.

Several factors were examined as possible explanations of lightning fire density variability between cover types. They included mean tree height and bulk density of four fuel components; litter, grasses and herbs, shrubs, and dead and down branchwood less than 3" in diameter. Mean tree height by species was computed using the FINSYS Forest Inventory/Stand Examination data base for the Lolo National Forest. Data on forest fuel bulk densities are scarce for Northern Region national forests, so bulk densities were computed from the Glacier National Park Basic Resource Inventory⁴. No data were available at all for western white pine or grand fir. The computed mean tree heights and fuel bulk densities for each cover type used in the correlation analysis are presented in Table 3.2.

Correlations of lightning fire density with mean tree height and four fuel bulk densities were computed for the seven cover types having fuel bulk density data available. Correlation coefficients were significant for mean tree height ($r = 0.61$) and the natural logarithm transformations of fuel bulk densities for grasses and herbs ($r = -0.57$), litter ($r = -0.41$), shrubs ($r = -0.20$), and fine woody fuels ($r = -0.15$). All five variables together accounted for more than 97% of the variation in lightning fire density by cover type for the seven species. The combination of mean tree height and the natural logarithm of fuel bulk density for grasses and litter alone accounted for 94% of the data variation.

TABLE 3.2

MEAN TREE HEIGHT AND FUEL BULK DENSITIES

BY COVER TYPE

Dominant Cover Type	Tree Height	n	--- Fuel Bulk Densities (lb/ft ³) ---			
			Litter	Fine Dead	Grass	Shrub
Ponderosa Pine	110.0	7	0.777	0.506	0.051	0.022
Western Larch	120.0	27	1.168	0.349	0.061	0.042
Spruce	111.0	36	1.100	0.435	0.048	0.045
Western White Pine	95.0	0	-	-	-	-
Cedar - Hemlock	95.0	22	0.774	0.653	0.026	0.122
Grand Fir	115.0	0	-	-	-	-
Douglas-fir	99.0	36	1.203	0.611	0.061	0.048
Lodgepole Pine	83.0	59	0.906	0.358	0.086	0.032
Subalpine Types	80.0	33	1.149	0.566	0.118	0.038

The high degree of correlation between lightning fire density and mean tree height is difficult to explain, but may reflect the more open understory in stands of taller trees. Ponderosa pine and western larch stands, for example, tend to be more open to solar radiation and drying winds under the canopy than stands of shorter or more densely stocked species. Fires started in the taller, more open stands during lightning storms may therefore be more likely to hold over, increase perimeter, and become reported fires.

The high negative correlations between lightning fire density and fuel bulk densities demonstrate the importance of fuel packing in determining the probability of a firebrand such as lightning starting a fire. The less dense the fuel complex, the greater the air movement through it and the availability of oxygen for combustion. In general, the more porous fuels tend to ignite more easily from firebrands (even when moisture content is high), dry more quickly following wetting, and support faster fire spread than dense fuels. All these characteristics increase the probability that a firebrand will start a fire and that the fire will continue to burn and increase its perimeter until it is spotted and becomes a reported lightning fire. Excluding mean tree height, the natural logarithmic transformations of grass, litter, and shrub or fine woody fuel bulk densities alone account for over 88% of the variation in lightning fire densities by cover type.

Acres burned densities were also computed for lightning fires by cover type for the Lolo National Forest from 1955 through 1974 (Table 3.3). Ponderosa pine again had the highest value with an average of 980 acres burned per million acres each year. Lodgepole pine was the second highest with 326 acres burned/mm acres/year. Grand fir was the lowest with 7 acres burned annually per million acres. In terms of either lightning fire start density or acres burned, ponderosa pine is by far the most fire-prone cover type on the Lolo

TABLE 3.3

LIGHTNING FIRE ACRES BURNED DENSITY BY COVER TYPE

(Acres Burned/mm Acres/Year)

SPECIES	ACRES BURNED	%S.E.
PONDEROSA PINE	979.5	71.5
WESTERN LARCH	55.1	29.9
ENGELMAN SPRUCE	72.6	55.9
W. WHITE PINE	100.2	73.7
CEDAR-HEMLOCK	20.2	57.2
GRAND FIR	7.1	29.4
DOUGLAS-FIR	25.7	38.8
LODGEPOLE PINE	325.6	96.0
SUBALPINE SPP.	48.8	56.2

National Forest. Ranking the other cover types behind ponderosa pine raises the problem of how much importance to give fire occurrence versus acres burned. If an arbitrary 50-50 weighting is applied to both the lightning fire occurrence density and the acres burned density to produce a synthetic measure of lightning fire risk and hazard, the relative order of cover types changes from the fire occurrence density table in only one significant respect; lodgepole pine becomes the second most fire-prone type behind ponderosa pine. Lodgepole will maintain its number two ranking as the weighting system is altered until fire occurrence density is weighted by more than 0.70.

3.2.2 Management Status Effects

Of the 1454 lightning fires started within the nine major cover types on the Lolo National Forest from 1955 through 1974, 1391 were coded according to the management status of the stand in which they started. Standing timber sites had 1239 fires while harvested/undisposed and harvested/disposed sites had 61 and 91 lightning fires, respectively (Table 3.4). The average acreage distribution between the three status classes for the twenty year period was 1,742,270 acres of standing timber, 57,573 acres of harvested/undisposed areas, and 14,803 acres of harvested/disposed sites.

Significant differences in lightning fire densities were found between the three management status classes for the Lolo National Forest. Standing timber had the lowest lightning fire density at 36 starts/mm acres/year. Fire start density increased to 106 fires per million acres annually on harvested/undisposed sites. Surprisingly, a dramatic increase in lightning fire density was found for those sites which had received some form of hazard reduction and/or site preparation -- 585 lightning fires/million acres/year on harvested/disposed sites.

TABLE 3.4
LIGHTNING FIRE DENSITY BY STAND
MANAGEMENT STATUS
LOLO NATIONAL FOREST : 1955 - 1974
(Fires/mm Acres/Year)

STAND CONDITION	LEVEL 1	NET AVERAGE
STANDING TIMBER	35.8 (13.0%) 1239 1742269.9 ^{1/}	38.3 (9.1%) 1391 1814645.9 (0.0%)
HARVESTED / UNDISPOSED	105.9 (24.1%) 61 57573.0	
HARVESTED / DISPOSED	584.9 (21.2%) 91 14803.0	

^{1/} Average acres in management status class from 1955 through 1974.

FIRE DENSITY	(%SE)
FIRE NUMBER	
ACRES	(%SE)

Several possible explanations were investigated for the sharp increase in lightning fire density on stands which have been treated for the purpose of reducing fire hazard. The first hypothesis tested was that forest managers tend to preferentially treat those sites which have traditionally been considered to pose a high fire risk and/or fire hazard, and even though the hazard has been reduced, the risk is still there (because of the site's elevation, aspect, or topography). The hypothesis was tested by comparing the distribution of harvested acreages by cover type with the distribution of treated areas by cover type and computing a chi-square statistic (Table 3.5). The statistic tests the hypothesis that fire managers are random (or unbiased) in their selection of which cover types to treat, and therefore the proportional distribution of treated areas should be the same as that of harvested areas. The computed chi-square statistic for the table is highly significant, and the hypothesis of randomness must be rejected. Although there is some evidence that ponderosa pine, spruce, and western larch have received priority treatment over other cover types (the actual treated acreages for these types exceed those predicted by the random hypothesis), the table shows no distinct tendency towards hazard reduction or site preparation in cover types traditionally considered to have a high fire risk.

Similar hypotheses of random hazard reduction and site preparation by elevation, aspect, and slope classes were tested (Tables 3.6, 3.7, and 3.8, respectively). Again, all tables had a highly significant chi-square statistic, and the hypothesis of randomness was rejected. If anything, the tables showed a tendency towards treatment of the less hazardous and low risk sites. More acres were actually treated for the less steep (under 45% slope) sites and northerly and easterly aspects than predicted by the random model. Such bias would leave a higher proportion of harvested/undisposed

TABLE 3.5
HARVESTED VS TREATED ACRES BY COVER TYPE
LOLO NATIONAL FOREST

COVER TYPE	HARVESTED ^{1/}	ACTUAL ^{2/} TREATED	PREDICTED ^{3/} TREATED	DIFFERENCE
Ponderosa Pine	39118	20825	18152	2673
Douglas-fir	108515	43449	50335	-6906
Lodgepole Pine	22404	9929	10396	- 467
Spruce	8606	5567	3993	1574
Western Larch	31610	19244	14668	4576
Grand Fir	5836	1892	2708	- 816
White Pine	209	48	97	- 49
Cedar - Hemlock	1376	519	639	- 120
Subalpine Types	13741	5912	6376	- 464
Total	231415	107385	107385	0

1/ Total acres harvested from Stand Examination and Management Status Record.

2/ Total acres receiving hazard reduction or site preparation from Stand Examination and Management Status Record.

3/ Total acres predicted by random model assuming same proportion of treated acres by cover type as harvested acres by cover type.

TABLE 3.6
HARVESTED VS TREATED ACRES BY ELEVATION
LOLO NATIONAL FOREST

ELEVATION BAND	HARVESTED ^{1/}	ACTUAL ^{2/} TREATED	PREDICTED ^{3/} TREATED	DIFFERENCE
2000 - 2999 ft	2009	1027	922	105
3000 - 3999 ft	23452	9311	10761	-1450
4000 - 4999 ft	117594	52815	53957	-1142
5000 - 5999 ft	96246	43280	44162	- 882
6000 - 6999 ft	16250	10586	7456	3130
7000 - 7999 ft	181	181	83	98
8000 - 8999 ft	304	280	139	141
Total	256063	117480	117480	0

1/ Total acres harvested from Stand Examination and Management Status Record.

2/ Total acres receiving hazard reduction or site preparation from Stand Examination and Management Status Record.

3/ Total acres predicted by random model assuming same proportion of treated acres by elevation band as harvested acres by elevation band.

TABLE 3.7
HARVESTED VS TREATED ACRES BY ASPECT
LOLO NATIONAL FOREST

ASPECT	^{1/} HARVESTED	^{2/} ACTUAL TREATED	^{3/} PREDICTED TREATED	DIFFERENCE
North	20050	9837	9294	543
Northeast	30105	16059	13955	2104
East	25764	12637	11943	424
Southeast	39347	15393	18239	-2846
South	34986	13695	16217	-2522
Southwest	34288	15354	15894	- 540
West	23277	10313	10790	- 477
Northwest	29383	14989	13620	1369
Flat	13958	8415	6470	1945
Total	251158	116422	116422	0

1/ Total acres harvested from Stand Examination and Management Status Record.

2/ Total acres receiving hazard reduction or site preparation from the Stand Examination and Management Status Record.

3/ Total acres predicted by the random model assuming the same proportion of treated acres by aspect class as harvested acres by aspect class.

TABLE 3.8

HARVESTED VS TREATED ACRES BY SLOPE

LOLO NATIONAL FOREST

SLOPE CLASS	^{1/} HARVESTED	^{2/} ACTUAL TREATED	^{3/} PREDICTED TREATED	DIFFERENCE
0% - 15%	21032	12399	9858	2541
16% - 25%	31950	19420	14975	4445
26% - 35%	42313	22084	19832	2252
36% - 45%	52385	24871	24553	318
46% - 55%	54431	21099	25512	-4413
56% - 65%	36101	12014	16921	-4907
66% - 75%	7265	3148	3405	- 257
75% - 85%	776	328	364	- 36
85% +	135	119	63	56
Total	246388	115482	115482	0

1/ Total acres harvested from Stand Examination and Management Status Record.

2/ Total acres receiving hazard reduction or site preparation from Stand Examination and Management Status Record.

3/ Total acres predicted by random model assuming same proportion of treated acres by slope class as harvested acres by slope class.

sites on steeper slopes and southerly aspects, sites usually considered to have high fire risk. One may ask why, then, should harvested stands that have been disposed have such a high lightning fire density, especially since they tend to occur on northerly and easterly aspects?

The conclusion reached was that fire managers by and large have not shown a strong bias towards treating slash units on sites that are generally considered to have high fire risk, and other explanations of the high lightning fire density on harvested/disposed stands are needed.

One possible explanation is that hazard reduction and site preparation practices may actually increase the fuel hazard on harvested/disposed sites. Prescribed burning may reduce total fuel load but also stimulate growth of grasses, nonwoody herbs, shrubs, and other small, porous fuels. Hand and dozer piling and other methods of machine scarification may have the same net effect by increasing exposed mineral soil and improving seedbed conditions for fine, live fuels. Such fuels typically establish themselves shortly after treatment, and cure as the fire season progresses. Domination of the fuels complex by the fine, standing fuels may last for several decades. It is interesting to note that 79% of all areas receiving hazard reduction or site preparation are treated by prescribed burning, hand piling, dozer piling, dozer terracing, or dozer scarifying on the Lolo National Forest. Disposed sites may also receive greater amounts of solar radiation and air movement through the porous fuel complex than undisposed areas where large fuel accumulations may actually insulate the fuel complex from drying winds and radiation.

Unlike forest cover types, fuel bed bulk density data are not available for correlation analysis with lightning fire density by cover type and stand management status class. It may be possible to infer that if bulk density exerts such a strong influence on the density of reported lightning fires by

cover type, that a similar influence may be exerted over lightning fire density by management status class.

Table 3.9 shows the average annual acres burned per million acres of management status class by lightning fires on the Lolo National Forest. Standing timber had the lowest acres burned density with 114 acres per year. Harvested/undisposed and harvested/disposed sites had lightning fire acres burned densities of 607 and 543 acres burned/mm acres/year, respectively. The difference between the two was not significant. Division of the acres burned density by the fire occurrence density yields the average acres burned per fire. Average fire size in standing timber was 3.2 acres, 5.7 acres for harvested/undisposed stands, and 0.9 acres for harvested/disposed sites. The lower acres burned per fire value for disposed sites indicates that even though harvested/disposed areas have a high fire risk and acres burned density, fires within them are easier to control than in undisposed sites.

3.2.3 Cover Type and Management Status Interactive Effects

Table 3.10 shows the mean annual lightning fire densities and total number of lightning fire starts by cover type and management status classes on the Lolo National Forest from 1955 to 1974, inclusive. Western white pine and cedar/hemlock had no lightning fires in either the harvested/undisposed or harvested/disposed classes during the twenty year period. Of the remaining seven cover types, all but the spruce class showed harvested/disposed sites to have the highest lightning fire density of the three management status classes.

The four cover types with the lowest average lightning fire density -- grand fir, Douglas-fir, lodgepole pine, and subalpine types -- all showed the same increase in fire density as the stand progressed from standing timber to harvested/undisposed to harvested/disposed. The two highest lightning fire density cover types, ponderosa pine and western larch, showed a decrease in

TABLE 3.9
 LIGHTNING FIRE ACRES BURNED DENSITY
 BY MANAGEMENT STATUS CLASS
 LOLO NATIONAL FOREST : 1955 - 1974

(Acres Burned/mm Acres/Year)

STAND CONDITION	ACRES BURNED	%S.E.
STANDING TIMBER	113.9	76.9
HARVESTED / UNDISPOSED	606.8	60.5
HARVESTED / DISPOSED	543.0	69.4

TABLE 3,10

LIGHTNING FIRE DENSITY BY COVER TYPE
AND MANAGEMENT STATUS

LOLO NATIONAL FOREST : 1955 - 1974

(Fires/mm Acres/Year)

SPECIES	STANDING TIMBER	HARV/UNDISPOSED	HARV/DISPOSED
Ponderosa Pine	497.3 381	168.2 23	1362.6 52
Western Larch	176.6 115	61.1 6	472.2 12
Spruce	155.9 51	50000.0 1	70.2 2
Western White Pine	144.9 6	0 0	0 0
Cedar - Hemlock	31.1 13	0 0	0 0
Grand Fir	22.2 41	45.7 3	1315.8 1
Douglas-fir	22.3 299	73.5 18	708.3 18
Lodgepole Pine	21.6 210	71.1 6	171.4 5
Subalpine Types	16.1 122	84.7 3	0 0

FIRE DENSITY TOTAL FIRES

fire density from standing timber to harvested/undisposed stand conditions. This may reflect the change in the fuel complex from light, porous fuels under open standing timber to heavier, more compact slash fuels in harvested, undisposed areas. Fire densities for both cover types increased dramatically in units which received hazard reduction or site preparation.

3.2.4 Elevation Effects

Of the five elevation bands examined on the Lolo National Forest, the 5000-5999 foot band had the highest number of lightning fires, 464 from 1955 to 1974, inclusive (Table 3.11). It also had the greatest land area, 803,793 acres. Significant differences in lightning fire densities were found between elevation bands. Highest fire density occurred in the lowest elevations (less than 4000 feet) with 70 starts/million acres/year. Densities remained fairly constant from 4000 to 7000 feet, averaging 34 starts/million acres annually, and increased to 56 fires each year above 7000 feet.

3.2.5 Aspect Effects

Table 3.12 shows the distribution of acreages to be fairly constant among the four cardinal aspects on the Lolo National Forest, with slightly more area on easterly and westerly slopes. This is not unexpected as the major mountain formations in the Lolo are oriented in a north-south direction.

The eight original aspect classes, when grouped into four classes corresponding to the cardinal compass points, showed significant differences in their mean lightning fire densities. South aspects were highest at 62 starts/million acres/year, and west aspects lowest at 22 starts/million acres annually. East and north aspect were intermediate at 36 and 37 fires/million acres/year, respectively. Level areas had the highest lightning fire density of all nine classes with 67 ignitions reported each year. The four aspect classes and

TABLE 3.11

LIGHTNING FIRE DENSITY BY ELEVATION BAND

LOLO NATIONAL FOREST ; 1955 - 1974

ELEVATION BAND	LEVEL 1	LEVEL 2	GROSS AVG
< 4000 FT	70.0 (12.0%) 231 164986.0 (19.9%)	70.0 (12.0%) 231 164986.0 (19.9%)	38.2 (9.1%) 1513 1978372.8 (0.0%)
4000-4999 FT	39.2 (12.9%) 433 552111.0 (7.8%)	34.3 (14.1%) 1186 1727282.9 (2.3%)	
5000-5999 FT	28.9 (15.6%) 464 803792.9 (6.0%)		
6000-6999 FT	38.9 (21.8%) 289 371379.1 (11.3%)		
≥ 7000 FT	55.7 (14.9%) 96 86103.9 (25.3%)	55.7 (14.9%) 96 86103.9 (25.3%)	

(Fires/mm Acres/Year)

FIRE DENSITY	(%SE)
FIRE NUMBER	
ACRES	(%SE)

LIGHTNING FIRE DENSITY BY ASPECT CLASS

LOLO NATIONAL FOREST : 1955 - 1974

PECT	LEVEL 1	LEVEL 2	LEVEL 3	GROSS AVG
LEVEL	67.2 (15.6) 77 57276.7 (23.0)	67.2 (15.6) 77 57276.7 (23.0)	62.9 (11.4) 544 432425.6 (8.5)	38.2 (9.1) 1512 1978372.8 (0.0)
SOUTH	63.4 (12.8) 290 228772.8 (10.6)	62.2 (11.2) 467 375148.9 (9.2)		
SOUTHWEST	60.5 (11.1) 177 146376.0 (17.3)			
WEST	37.7 (14.3) 145 192466.1 (14.1)	22.0 (12.7) 239 543955.3 (9.2)		
NORTHWEST	13.4 (14.9) 94 351489.2 (12.6)			
NORTH	41.6 (14.8) 201 241744.5 (13.1)	37.0 (14.1) 340 459845.7 (10.5)	31.3 (12.9) 968 1545947.3 (2.4)	
NORTHEAST	31.9 (15.0) 139 218101.2 (17.8)			
EAST	36.7 (16.8) 173 235557.3 (14.1)	35.9 (14.0) 389 542146.3 (8.9)		
SOUTHEAST	35.2 (13.3) 216 306589.0 (11.9)			

(Fires/mm Acres/Year)

FIRE DENSITY	(%SE)
FIRE NUMBER	
ACRES	(%SE)

level class break themselves into two distinct groups with respect to lightning fire occurrence density. Level and southerly aspects have the highest density, averaging 63 starts/mm acres/year. All other aspects have an average annual density of 31 lightning fires.

The high density of lightning fires on southerly aspects is perhaps best accounted for by the tendency of lightning storms to move in a northerly and easterly direction across the Lolo National Forest. South aspects are also drier, increasing the probability of a firebrand starting a reportable fire. The high fire density on level areas was unexpected, however. It is accounted for by the inclusion of ridgetop fires in the level aspect class. Ridgetop fires were assigned to the level class because no corresponding ridgetop acreages were available, and aspects could not be assigned to those fires starting on ridges. Of the 77 fires in the level aspect class, 34 were started on ridgetops. Exclusion of the ridgetop fires dropped the lightning fire density on level aspects to 37.5 ignitions/mm acres/year, which would place it in the low fire density aspect group along with north, east, and west aspects. If the total ridgetop acreage on the Lolo Forest is less than about 30,000 acres, ridgetop areas would have a lightning fire density similar to that of south aspects.

3.2.6 Slope Effects

Slope also showed a highly significant effect on lightning fire densities on the Lolo National Forest from 1955 to 1974, inclusive. Table 3.13 shows 80% of the forest's area to be on slopes less than 45%, while only 66% of all lightning fires occur there. Lightning fire density is therefore highest on the steeper slopes; 638 fires/mm acres/year for slopes over 75%. The next highest fire density is found for slopes under 15%, with 127 starts per million acres annually. Lightning fire density steadily declines as slope

LIGHTNING FIRE DENSITY BY SLOPE CLASS

LOLO NATIONAL FOREST : 1955 - 1974

PE CLASS	LEVEL 1	LEVEL 2	LEVEL 3	GROSS	AVG
0 - 15 %	126.7 (18.6) 267 105406.5 (18.8)	126.7 (18.6) 267 105406.5 (18.8)	126.7 (18.6) 267 105406.5 (18.8)	28.9 (11.7) 1073 1859361.0 (1.1)	38.2 (9.1) 1513 1978372.8 (0.0)
16 - 25 %	44.8 (20.6) 154 172056.3 (17.2)	33.3 (15.8) 366 549490.2 (8.6)			
26 - 35 %	28.1 (13.7) 212 377433.9 (10.4)				
36 - 45 %	20.7 (13.7) 182 439008.7 (9.1)	19.5 (10.4) 359 921081.2 (5.6)			
46 - 55 %	18.4 (12.2) 177 482072.5 (8.2)				
56 - 65 %	39.4 (12.6) 215 272517.1 (11.3)	44.8 (13.3) 348 388789.7 (9.9)			
66 - 75 %	57.2 (17.2) 133 116272.6 (23.4)				
76 - 85 %	308.4 (15.9) 68 11023.3 (58.6)	638.1 (15.5) 173 13605.3 (50.2)			
>85 %	2033.3 (17.9) 105 2582.0 (86.1)				

(Fires/mm Acres/Year)

FIRE DENSITY	(%SE)
FIRE NUMBER	
ACRES	(%SE)

increases from zero to 45%, and then increases steadily as slope steepness increases.

3,2,7 Cover Type and Elevation, Aspect, and Slope Interactive Effects

Tables 3,14, 3,15, and 3,16 show the interactive effects of cover type and elevation, aspect, and slope, respectively, on lightning fire occurrence densities. Chi-square analysis showed highly significant interactive effects, but trends are difficult to recognize. Part of the problem arises from spreading the Forest Inventory/Stand Examination acreage data too thinly between two simultaneous stratifications. This is especially evident in Table 3,14 where the only cover type with acreage above 7000 feet is the subalpine class, even though lightning fires have occurred above 7000 feet in ponderosa pine, western larch, spruce, grand fir, Douglas-fir, and lodgepole pine stands. Similar problems arise in both the cover type by aspect and cover type by slope tables.

3,2,8 Elevation, Aspect, and Slope Interactive Effects

Tables 3,17, 3,18, and 3,19 show the interactive effects of elevation, aspect, and slope, respectively, on lightning fire densities on the Lolo National Forest. Chi-square tests showed significant interactive effects for all three cross-stratifications. Lightning fire density trends within each table reflect the higher level one-way patterns of each stratification by itself.

LIGHTNING FIRE DENSITY BY COVER TYPE AND ELEVATION BAND

LOLO NATIONAL FOREST : 1955 - 1974

SPECIES	<4000 FT	4000 - 6999 FT	≥ 7000 FT	GROSS SPP AVG
PONDEROSA PINE	315.5 (13.0) 144 22824.5 (32.5)	587.0 (10.9) 343 29217.1 (36.0)	0.0 2 0.0	469.8 (9.8) 489 52041.6 (23.9)
WESTERN LARCH	276.0 (39.0) 12 2173.8 (66.8)	156.9 (19.7) 121 38568.9 (28.9)	0.0 3 0.0	166.9 (18.2) 136 40742.8 (27.6)
ENGELMAN SPRUCE	0.0 0 0.0	129.0 (25.9) 48 18599.0 (35.2)	0.0 7 0.0	147.9 (25.0) 55 18599.0 (35.2)
W. WHITE PINE	0.0 0 0.0	136.6 (54.6) 6 2196.5 (68.4)	0.0 0 0.0	136.6 (54.6) 6 2196.5 (68.4)
CEDAR-HEMLOCK	6.4 (99.9) 1 7758.6 (68.7)	48.1 (20.2) 13 13514.1 (48.9)	0.0 0 0.0	32.9 (21.0) 14 21272.7 (40.5)
GRAND FIR	4.6 (54.6) 3 32586.8 (41.3)	33.1 (21.0) 41 61873.4 (30.9)	0.0 3 0.0	24.9 (19.6) 47 99460.3 (24.3)
DOUGLAS-FIR	44.3 (25.2) 51 57518.7 (33.3)	22.3 (16.4) 291 651106.0 (6.6)	0.0 10 0.0	24.8 (14.1) 352 708624.7 (6.4)
LODGEPOLE PINE	234.4 (36.1) 11 2346.9 (99.9)	20.1 (21.1) 197 490557.5 (6.4)	0.0 19 0.0	23.0 (19.3) 227 492904.4 (6.4)
SUBALPINE SPP.	0.0 0 0.0	12.3 (23.8) 80 325870.0 (12.3)	41.4 (20.1) 48 57934.1 (31.1)	16.7 (20.0) 128 383804.0 (10.4)

(Fires/mm Acres/Year)

FIRE DENSITY	(%SE)
FIRE NUMBER	
ACRES	(%SE)

LIGHTNING FIRE DENSITY BY COVER TYPE AND ASPECT CLASS

LOLO NATIONAL FOREST : 1955 - 1974

SPECIES	LEVEL; S; SW;	W; NW; N; NE; E; SE;	GROSS SPP AVG
PONDEROSA PINE	390.0 (10.8) 244 31278.2 (35.1)	590.0 (10.4) 245 20763.4 (31.4)	469.8 (9.8) 489 52041.5 (23.9)
WESTERN LARCH	183.0 (29.6) 35 9560.7 (51.8)	162.0 (18.1) 101 31182.0 (30.3)	166.9 (18.2) 136 40742.8 (27.6)
ENGELMAN SPRUCE	117.7 (34.0) 13 5523.7 (91.7)	160.6 (32.4) 42 13075.3 (31.7)	147.9 (25.0) 55 18599.0 (35.2)
W. WHITE PINE	0.0 2 0.0	91.1 (58.5) 4 2196.5 (68.4)	136.6 (54.6) 6 2196.5 (68.4)
CEDAR-HEMLOCK	0.0 0 7342.6 (54.9)	50.3 (21.0) 14 13930.1 (53.9)	32.9 (21.0) 14 21272.7 (40.5)
GRAND FIR	10.9 (37.5) 7 31980.8 (42.6)	32.0 (20.8) 40 62479.4 (29.8)	24.9 (19.6) 47 94460.3 (24.3)
DOUGLAS-FIR	32.5 (13.2) 112 172246.5 (13.3)	22.4 (16.0) 240 536378.2 (8.5)	24.8 (14.1) 352 708624.4 (6.4)
LODGEPOLE PINE	34.6 (23.0) 75 108441.2 (16.7)	19.8 (18.5) 152 384463.2 (8.1)	23.0 (19.3) 227 492904.4 (6.4)
SUBALPINE SPP.	39.4 (26.8) 33 41904.3 (29.6)	13.9 (19.6) 95 341899.7 (11.4)	16.7 (20.0) 128 383804.0 (10.4)

FIRE DENSITY	(%SE)
FIRE NUMBER	
ACRES	(%SE)

LIGHTNING FIRE DENSITY BY COVER TYPE AND SLOPE CLASS

LOLO NATIONAL FOREST : 1955 - 1974

SPECIES	0 - 15%	16 - 75%	75%	GROSS SPP AVG
PONDEROSA PINE	1377.4 (13.0) 75 2722.7 (61.3)	356.8 (10.1) 348 48773.4 (24.6)	6050.6 (17.0) 66 545.4 (99.9)	469.8 (9.8) 489 52041.5 (23.9)
WESTERN LARCH	164.4 (35.9) 29 8818.5 (55.1)	145.7 (15.6) 93 31924.3 (29.4)	0.0 14 0.0	166.9 (18.2) 136 40742.8 (27.6)
ENGELMAN SPRUCE	104.7 (39.0) 12 5731.3 (88.9)	143.8 (28.0) 37 12867.8 (31.9)	0.0 6 0.0	147.9 (25.0) 55 18599.0 (35.2)
W. WHITE PINE	106.9 (99.9) 1 467.7 (99.9)	144.6 (49.2) 5 1728.8 (81.8)	0.0 0 0.0	136.6 (54.6) 6 2196.5 (68.4)
CEDAR-HEMLOCK	11.3 (68.8) 2 8820.8 (48.5)	44.2 (24.6) 11 12452.7 (58.9)	0.0 1 0.0	32.9 (21.0) 14 21272.7 (40.5)
GRAND FIR	398.8 (22.9) 10 1253.9 (86.0)	18.8 (23.0) 35 93206.3 (24.7)	0.0 2 0.0	24.9 (19.6) 47 99460.3 (24.3)
DOUGLAS-FIR	404.5 (23.2) 49 6056.6 (69.4)	18.3 (13.7) 257 700450.1 (6.5)	1085.9 (18.1) 46 2118.0 (99.9)	24.8 (14.1) 352 708624.7 (6.4)
LODGEPOLE PINE	99.9 (19.4) 61 30528.0 (29.4)	16.9 (21.6) 156 461912.4 (6.7)	1077.4 (30.8) 10 464.1 (99.9)	23.0 (19.3) 227 492904.4 (6.4)
SUBALPINE SPP.	24.6 (41.0) 18 36653.8 (41.8)	12.7 (21.6) 86 337464.5 (10.7)	123.9 (30.6) 24 9685.7 (65.9)	16.7 (20.0) 128 383804.0 (10.4)

FIRE DENSITY	(%SE)
FIRE NUMBER	
ACRES	(%SE)

(Fires/mm Acres/Year)

TABLE 3.17

LIGHTNING FIRE DENSITY BY ELEVATION BAND AND SLOPE CLASS

LOLO NATIONAL FOREST : 1955 - 1974

ELEVATION	0 - 15%	16 - 75%	75%	GROSS AVG ELEV
< 4000 FT	123.1 (19.4)	54.6 (13.2)	2475.2 (24.2)	70.0 (12.0)
	44	160	27	231
	17869.5 (34.9)	14657.1 (21.3)	545.4 (99.9)	164986.0 (19.9)
4000 - 6999 FT	123.0 (23.1)	26.1 (13.2)	486.2 (17.2)	34.3 (14.1)
	209	850	127	1186
	84960.6 (22.1)	1629262.6 (2.6)	13059.9 (52.1)	1727283.0 (2.3)
≥ 7000 FT	271.7 (23.4)	37.7 (17.9)	0.0	55.7 (14.9)
	14	63	19	96
	2576.5 (80.9)	83527.4 (25.3)	0.0	86103.9 (25.3)

TABLE 3.18

LIGHTNING FIRE DENSITY BY ELEVATION BAND AND ASPECT CLASS

LOLO NATIONAL FOREST : 1955 - 1974

ELEVATION	LEVEL; S; SW;	N; NE; E; SE; W; NW;	GROSS AVG ELEV
< 4000 FT	98.3 (16.0)	55.1 (10.8)	70.0 (12.0)
	112	119	231
	56974.2 (25.8)	108011.8 (27.1)	164986.0 (19.9)
4000 - 6999 FT	54.9 (13.3)	28.8 (15.1)	34.3 (14.1)
	402	784	1186
	366406.1 (9.4)	1360876.9 (3.5)	1727283.0 (2.3)
≥ 7000 FT	165.8 (17.1)	42.2 (17.3)	55.7 (14.9)
	30	65	96
	9045.3 (55.5)	77058.6 (26.5)	86103.9 (25.3)

FIRE DENSITY	(%SE)
FIRE NUMBER	
ACRES	(%SE)

(Fires/mm Acres/Year)

TABLE 3.19

LIGHTNING FIRE DENSITY BY SLOPE AND ASPECT CLASS

LOLO NATIONAL FOREST : 1955 - 1974

SLOPE CLASS	LEVEL; S; SW;	N; NE; E; SE; W; NW;	GROSS AVG SLOPE
0 - 15%	91.2 (17.2) 131 71851.0 (19.4)	202.7 (22.2) 136 33555.5 (43.3)	126.7 (18.6) 267 105406.5 (18.8)
16 - 75%	49.2 (12.0) 355 360574.6 (9.5)	23.9 (12.0) 717 1498786.5 (2.6)	28.9 (11.7) 1073 1859361.0 (1.1)
> 75%	0.0 58 0.0	422.6 (18.1) 115 13605.3 (50.2)	638.1 (15.5) 173 13605.3 (50.2)

(Fires/mm Acres/Year)

FIRE DENSITY	(%SE)
FIRE NUMBER	
ACRES	(%SE)

3.3 TACTICAL LIGHTNING FIRE DENSITIES

Lightning fire densities by cover type, management status, elevation, aspect, and slope classes were divided into monthly and fifteen-day periods to show seasonal effects of fire occurrence. The results are presented in tables 3.20 through 3.29. For all classes of all stratifications, August was the month of highest lightning fire occurrence density on the Lolo National Forest during the twenty years from 1955 to 1974. July was the second highest lightning fire density month for all stratification classes. The only exception was harvested/undisposed sites, for which June was the month of highest lightning fire density.

Stratification by fifteen day periods did not produce any significant changes from the monthly breakdown of lightning fires. Lightning fire density was identical for the first and last fifteen day periods of August. For all stratification classes, the greatest lightning fire density occurred during one of the semi-monthly periods in August, and the second highest density occurred in either August or July. Again, the only exception was harvested/undisposed sites, where highest lightning fire density occurred during the first half of June.

TABLE 3,20

COVER TYPE LIGHTNING FIRE DENSITY BY MONTH

LOLO NATIONAL FOREST : 1955 - 1975

SPECIES	JAN- APR	MAY	JUN	JUL	AUG	SEP	OCT- DEC
PONDEROSA PINE	2.9 3	19.2 20	59.6 62	162.4 169	177.7 185	36.5 38	11.5 12
WESTERN LARCH	0.0 0	4.9 4	3.7 3	47.9 39	89.6 73	18.4 15	2.5 2
ENGELMAN SPRUCE	0.0 0	0.0 0	8.1 3	32.3 12	96.8 36	10.8 4	0.0 0
W. WHITE PINE	0.0 0	0.0 0	0.0 0	45.5 2	68.3 3	22.8 1	0.0 0
CEDAR-HEMLOCK	0.0 0	0.0 0	0.0 0	9.4 4	16.5 7	7.1 3	0.0 0
GRAND FIR	0.0 0	0.5 1	1.1 2	5.8 11	14.3 27	3.2 6	0.0 0
DOUGLAS-FIR	0.0 0	0.5 7	1.4 20	6.8 96	12.8 181	3.1 45	0.2 3
LODGEPOLE PINE	0.0 0	0.2 2	1.3 13	6.4 63	12.4 123	2.6 26	0.0 0
SUBALPINE SPP.	0.0 0	0.1 1	0.5 4	3.9 30	8.6 66	3.5 27	0.0 0
MONTH TOTAL*	0.1 3	1.0 36	3.1 111	12.1 439	20.3 736	4.7 170	0.5 18

* Includes missing data

FIRE DENSITY FIRE NUMBER

TABLE 3,21

COVER TYPE LIGHTNING FIRE DENSITY BY FIFTEEN DAY PERIOD

SPECIES	JAN- APR 30	MAY 15	MAY 30	JUN 15	JUN 30	JUL 15	JUL 31	AUG 15	AUG 31	SEP 15	SEP 30	OCT- DEC 31	CT TOTAL
PONDEROSA PINE	2.9 3	2.9 3	16.3 17	23.1 24	36.5 38	91.3 95	71.1 74	95.1 99	82.6 86	35.5 37	1.0 1	11.5 12	469.8 489
WESTERN LARCH	0.0 0	0.0 0	4.9 4	1.2 1	2.5 2	22.1 18	25.8 21	47.9 39	41.7 34	17.2 14	1.2 1	2.5 2	166.9 136
ENGELMAN SPRUCE	0.0 0	0.0 0	0.0 0	2.7 1	5.4 2	18.8 7	13.4 5	37.6 14	59.1 22	10.8 4	0.0 0	0.0 0	147.9 55
W. WHITE PINE	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	45.5 2	45.5 2	22.8 1	22.8 1	0.0 0	0.0 0	136.6 6
CEDAR-HEMLOCK	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	9.4 4	4.7 2	11.8 5	4.7 2	2.4 1	0.0 0	32.9 14
GRAND FIR	0.0 0	0.5 1	0.0 0	0.5 1	0.5 1	1.6 3	4.2 8	6.4 12	7.9 15	3.2 6	0.0 0	0.0 0	24.9 47
DOUGLAS-FIR	0.0 0	0.0 0	0.5 7	0.3 4	1.1 16	2.3 40	4.0 56	7.5 106	5.3 75	2.7 38	0.5 7	0.2 3	24.8 352
LODGEPOLE PINE	0.0 0	0.0 0	0.2 2	0.0 0	1.3 13	3.1 31	3.2 32	5.0 49	7.5 74	2.4 24	0.2 2	0.0 0	23.0 227
SUBALPINE SPP.	0.0 0	0.0 0	0.1 1	0.0 0	0.5 4	1.4 11	2.5 19	3.8 29	4.8 37	3.5 27	0.0 0	0.0 0	16.7 128
PERIOD TOTAL*	0.1 3	0.1 4	0.9 32	0.9 32	2.2 79	5.8 212	6.3 227	10.2 369	10.2 367	4.3 157	0.4 13	0.5 18	

* Includes missing data

FIRE DENSITY FIRE NUMBER

TABLE 3.21

COVER TYPE LIGHTNING FIRE DENSITY BY FIFTEEN DAY PERIOD
LOLO NATIONAL FOREST : 1955 - 1974

SPECIES	JAN- APR 30	MAY 15	MAY 30	JUN 15	JUN 30	JUL 15	JUL 31	AUG 15	AUG 31	SEP 15	SEP 30	OCT- DEC 31	CT TOTAL
PONDEROSA PINE	2.9 3	2.9 3	16.3 17	23.1 24	36.5 38	91.3 95	71.1 74	95.1 99	82.6 86	35.5 37	1.0 1	11.5 12	469.8 489
WESTERN LARCH	0.0 0	0.0 0	4.9 4	1.2 1	2.5 2	22.1 18	25.8 21	47.9 39	41.7 34	17.2 14	1.2 1	2.5 2	166.9 136
ENGELMAN SPRUCE	0.0 0	0.0 0	0.0 0	2.7 1	5.4 2	18.8 7	13.4 5	37.6 14	59.1 22	10.8 4	0.0 0	0.0 0	147.9 55
W. WHITE PINE	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	45.5 2	45.5 2	22.8 1	22.8 1	0.0 0	0.0 0	136.6 6
CEDAR-HEMLOCK	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	9.4 4	4.7 2	11.8 5	4.7 2	2.4 1	0.0 0	32.9 14
GRAND FIR	0.0 0	0.5 1	0.0 0	0.5 1	0.5 1	1.6 3	4.2 8	6.4 12	7.9 15	3.2 6	0.0 0	0.0 0	24.9 47
DOUGLAS-FIR	0.0 0	0.0 0	0.5 7	0.3 4	1.1 16	2.3 40	4.0 56	7.5 106	5.3 75	2.7 38	0.5 7	0.2 3	24.8 352
LODGEPOLE PINE	0.0 0	0.0 0	0.2 2	0.0 0	1.3 13	3.1 31	3.2 32	5.0 49	7.5 74	2.4 24	0.2 2	0.0 0	23.0 227
SUBALPINE SPP.	0.0 0	0.0 0	0.1 1	0.0 0	0.5 4	1.4 11	2.5 19	3.8 29	4.8 37	3.5 27	0.0 0	0.0 0	16.7 128
PERIOD TOTAL*	0.1 3	0.1 4	0.9 32	0.9 32	2.2 79	5.8 212	6.3 227	10.2 369	10.2 367	4.3 157	0.4 13	0.5 18	

* Includes missing data

FIRE DENSITY
FIRE NUMBER

MANAGEMENT STATUS LIGHTNING FIRE DENSITY BY MONTH

LOLO NATIONAL FOREST : 1955 - 1974

MONTH	STANDING TIMBER	HARVESTED - NOT DISPOSED	HARVESTED- DISPOSED	MONTHLY TOTAL *
JAN - APR	0.1 2	0.0 0	14.9 1	0.1 3
MAY	0.9 31	0.0 0	12.0 3	1.0 36
JUNE	2.4 83	37.6 11	45.6 6	3.1 111
JULY	10.4 362	32.9 22	151.8 25	12.1 439
AUGUST	17.8 614	11.9 20	182.7 36	20.3 736
SEPTEMBER	3.9 133	3.7 7	82.8 19	4.7 170
OCT - DEC	0.4 14	6.1 1	14.9 1	0.5 18

* Includes missing data

FIRE DENSITY
FIRE NUMBER

TABLE 3.23

MANAGEMENT STATUS LIGHTNING FIRE DENSITY BY FIFTEEN DAY PERIOD

LOLO NATIONAL FOREST : 1955 - 1974

PERIOD	STANDING TIMBER	HARVESTED - NOT DISPOSED	HARVESTED - DISPOSED	PERIOD TOTAL *
JAN - APR 30 (1)	0.1 2	0.0 0	14.9 1	0.1 3
MAY 1 - 15 (2)	0.1 4	0.0 0	0.0 0	0.1 4
MAY 16 - 31 (3)	0.8 27	0.0 0	12.0 3	0.9 32
JUN 1 - 15 (4)	0.6 21	28.9 5	24.5 2	0.9 32
JUN 16 - 30 (5)	1.8 62	8.7 6	21.1 4	2.2 79
JUL 1 - 15 (6)	4.8 169	20.6 12	97.5 15	5.8 212
JUL 16 - 31 (7)	5.6 193	12.3 10	54.4 10	6.3 227
AUG 1 - 15 (8)	8.6 297	6.4 13	85.9 18	10.2 369
AUG 16 - 31 (9)	9.2 317	5.5 7	96.8 18	10.1 367
SEP 1 - 15 (10)	3.5 122	3.7 7	73.6 18	4.3 157
SEP 16 - 30 (11)	0.3 11	0.0 0	9.2 1	0.4 13
OCT - DEC 31 (12)	0.4 14	6.1 1	14.9 1	0.5 18

* Includes missing data

FIRE DENSITY

FIRE NUMBER

TABLE 3,24

ELEVATION BAND LIGHTNING FIRE DENSITY BY MONTH

LOLO NATIONAL FOREST : 1955 - 1974

MONTH	≤4000	4000 - 6999	>7000	MONTHLY TOTAL
JAN - APR	0.9 3	0.0 0	0.0 0	0.1 3
MAY	3.3 11	0.7 25	0.0 0	0.9 36
JUNE	9.7 32	2.3 78	0.6 1	2.8 111
JULY	23.9 79	9.7 335	14.5 25	11.1 439
AUGUST	24.9 82	17.5 603	29.6 51	18.6 736
SEPTEMBER	6.1 20	3.8 131	11.0 19	4.3 170
OCT - DEC	1.2 4	0.4 14	0.0 0	0.5 18

FIRE DENSITY

FIRE NUMBER

TABLE 3.25

ELEVATION BAND LIGHTNING FIRE DENSITY BY FIFTEEN DAY PERIOD

LOLO NATIONAL FOREST : 1955 - 1974

PERIOD	4000	4000 - 6999	,GT, 7000	PERIOD TOTAL
JAN - APR 30 (1)	0.9 3	0.0 0	0.0 0	0.1 3
MAY 1 - 15 (2)	0.6 2	0.1 2	0.0 0	0.1 4
MAY 16 - 31 (3)	2.7 9	0.7 23	0.0 0	0.8 32
JUN 1 - 15 (4)	3.3 11	0.6 21	0.0 0	0.8 32
JUN 16 - 30 (5)	6.4 21	1.7 57	0.6 1	2.0 79
JUL 1 - 15 (6)	14.2 47	4.5 155	5.8 10	5.4 212
JUL 16 - 31 (7)	9.7 32	5.2 180	8.7 15	5.7 227
AUG 1 - 15 (8)	14.9 49	8.6 296	13.9 24	9.3 369
AUG 16 - 31 (9)	10.0 33	8.9 307	15.7 27	9.3 367
SEP 1 - 15 (10)	5.5 18	3.5 121	10.5 18	4.0 157
SEP 16 - 30 (11)	0.6 2	0.3 10	0.6 1	0.3 13
OCT - DEC 30 (12)	1.2 4	0.4 14	0.0 0	0.5 18

FIRE DENSITY

FIRE NUMBER

TABLE 3.26

ASPECT LIGHTNING FIRE DENSITY BY MONTH

LOLO NATIONAL FOREST : 1955 - 1974

MONTH	LEVEL; S; SW;	N; NE; E; SE; W; NW;	MONTHLY TOTAL
JAN - APR	0.1 1	0.1 2	0.1 3
MAY	2.4 21	0.5 15	0.9 36
JUNE	5.7 49	2.0 62	2.8 111
JULY	20.1 174	8.6 265	11.1 439
AUGUST	27.9 241	16.0 494	18.6 736
SEPTEMBER	6.2 53	3.8 117	4.3 170
OCT - DEC	0.6 5	0.4 13	0.5 18

FIRE DENSITY

FIRE NUMBER

TABLE 3,27

ASPECT LIGHTNING FIRE DENSITY BY FIFTEEN DAY PERIOD

LOLO NATIONAL FOREST : 1955 - 1974

PERIOD	LEVEL; S; SW;	N; NE; E; SE; W; NW;	PERIOD TOTAL
JAN - APR 30 (1)	0.1 1	0.1 2	0.1 3
MAY 1 - 15 (2)	0.2 2	0.1 2	0.1 4
MAY 16 - 31 (3)	2.2 19	0.4 13	0.8 32
JUN 1 - 15 (4)	1.9 16	0.5 16	0.8 32
JUN 16 - 30 (5)	3.8 33	1.5 46	2.0 79
JUL 1 - 15 (6)	11.4 99	3.7 113	5.4 212
JUL 16 - 31 (7)	8.7 75	4.9 152	5.7 227
AUG 1 - 15 (8)	14.6 126	7.9 243	9.3 369
AUG 16 - 31 (9)	13.3 115	8.1 251	9.3 367
SEP 1 - 15 (10)	5.4 47	3.6 110	4.0 157
SEP 16 - 31 (11)	0.7 6	0.2 7	0.3 13
OCT - DEC 30 (12)	0.6 5	0.4 13	0.5 18

FIRE DENSITY

FIRE NUMBER

TABLE 3.28

SLOPE LIGHTNING FIRE DENSITY BY MONTH

LOLO NATIONAL FOREST : 1955 - 1974

MONTH	0 - 15%	16 - 75%	75%	MONTHLY TOTAL
JAN - APR	0.0 0	0.1 3	0.0 0	0.1 3
MAY	5.7 12	0.5 20	14.7 4	0.9 36
JUNE	8.5 18	2.1 77	58.8 16	2.8 111
JULY	34.6 73	8.5 315	187.4 51	11.1 439
AUGUST	57.4 121	14.1 526	327.1 89	18.6 736
SEPTEMBER	19.9 42	3.1 116	44.1 12	4.3 170
OCT - DEC	0.4 1	0.4 16	3.7 1	0.5 18

FIRE DENSITY

FIRE NUMBER

TABLE 3.29

SLOPE LIGHTNING FIRE DENSITY BY FIFTEEN DAY PERIOD

LOLO NATIONAL FOREST : 1955 - 1974

PERIOD	0 - 15%	16 - 75%	75%	PERIOD TOTAL
JAN - APR 30 (1)	0.0 0	0.1 3	0.0 0	0.1 3
MAY 1 - 15 (2)	0.9 2	0.1 2	0.0 0	0.1 4
MAY 16 - 31 (3)	4.7 10	0.5 18	14.7 4	0.8 32
JUN 1 - 15 (4)	3.3 7	0.5 19	22.1 6	0.8 32
JUN 16 - 30 (5)	5.2 11	1.6 58	36.8 10	2.0 79
JUL 1 - 15 (6)	16.1 34	4.0 150	102.9 28	5.4 212
JUL 16 - 31 (7)	18.5 39	4.4 165	84.5 23	5.7 227
AUG 1 - 15 (8)	30.8 65	6.9 257	172.7 47	9.3 369
AUG 16 - 31 (9)	26.6 56	7.2 269	154.4 42	9.3 367
SEP 1 - 15 (10)	18.0 38	2.9 107	44.1 12	4.0 157
SEP 16 - 30 (11)	1.9 4	0.2 9	0.0 0	0.3 13
OCT - DEC 30 (12)	0.5 1	0.4 16	3.7 1	0.5 18

FIRE DENSITY

FIRE NUMBER

3.4 STRATEGIC MAN-CAUSED FOREST FIRE DENSITY

3.4.1 Man-Caused Fire Category Effects

Of the 1922 forest fires reported on non-wilderness, federally-owned lands within Lolo National Forest fire protection boundaries from 1955 to 1974, 409 (21.3%) were man-caused. Man-caused forest fire densities for the twenty-year period averaged 10.3 starts/mm acres/year, compared to 38.2 starts/mm acres/year for lightning fires.

The type of activity that led to the man-caused fire had a significant effect on the average annual man-caused fire density. Activities related to recreation -- fishing, hunting, camping, hiking, etc. -- posed the greatest risk. Recreational activities accounted for 168 fires (41% of all man-caused fires) for a fire density of 4.3 starts/mm acres/year (see Table 3.33). Timber harvest, forest and range management, and related activities started 99 fires (24%), or 2.5 starts/mm acres/year. Man-caused fire density on highway, railroad, and powerline right-of-ways was the third highest at 1.3 starts/mm acres/year (52 fires, or 13%), and arsonists and children started another 36 fires (9%) for a fire density of 0.9. The remaining 55 man-caused fires were classified as "miscellaneous" or "other" on the individual fire reports.

3.4.2 Cover Type and Man-Caused Fire Category Effects

Table 3.30 shows a significant cover type effect on all five categories of man-caused forest fire density on the Lolo National Forest. The cover types fell into three distinct density groups. Ponderosa pine constitutes the highest group with a man-caused fire density of 107 starts/mm acres/year. Western larch, spruce, and western white pine made up the second group, where densities ranged from 22.8 starts/mm acres/year for western white pine to

TABLE 3.30

MAN-CAUSED FIRE DENSITY BY COVER TYPE

LOLO NATIONAL FOREST : 1955 - 1974

COVER TYPE	INDUS- TRIAL	FOREST MGMT	RECREA- TIONAL	INCENDRY CHILDREN	MISC OTHER	SPECIES AVERAGE
Ponderosa Pine	6.7 7	22.1 45	50.0 52	6.7 7	21.1 22	106.6 111
Western Larch	3.7 3	18.4 15	20.9 17	3.7 3	4.9 4	51.5 42
Spruce	5.4 2	26.9 10	21.5 8	2.7 1	2.7 1	59.1 22
Western White Pine	0 0	0 0	22.8 1	0 0	0 0	22.8 1
Red Cedar- W. Hemlock	0 0	7.1 3	2.4 1	4.7 2	0 0	14.1 6
Grand Fir	0 0	4.2 8	2.6 5	0.5 1	1.1 2	8.5 16
Douglas- fir	0.3 4	1.2 17	1.5 21	0.2 3	0.2 3	3.4 48
Lodgepole Pine	0.6 6	1.3 13	1.7 17	0.1 1	0.6 6	4.4 43
Subalpine Types	0 0	0.3 2	0.3 4	0 0	0 0	0.8 6
Category Average	0.6 22	2.5 91	3.5 126	0.5 18	1.0 38	8.1 295

Fire Density (Starts/mm Acres/Year)
Fire Number (Total : 1955 - 1974)

59.1 starts/mm acres/year for spruce. Cedar/hemlock, grand fir, Douglas-fir, lodgepole pine, and subalpine types constitute the third group. Man-caused fire density values for the low group ranged from 0.8 starts/mm acres/year in subalpine types to 14.1 starts/mm acres/year in cedar/hemlock stands.

The man-caused fire category also had a significant effect on fire density for each and all cover type classes, demonstrating the influence of the kind of activity on firebrand prevalence regardless of cover type. Recreational activities posed the greatest risk to ponderosa pine, western larch, western white pine, Douglas-fir, lodgepole pine, and subalpine cover types, and forest management activities were the greatest source of man-caused fires in spruce, cedar/hemlock, and grand fir types.

Some striking similarities are found when comparing cover type effects on man-caused fire densities with cover type effects on lightning fire densities. To begin with, the nine cover types arrange themselves into the same three distinct groups containing the same members for both fire causes. The same three cover type groups also generally apply to all five man-caused fire categories. Furthermore, the ranking of cover types by man-caused fire density has the same order as the ranking of cover types by lightning fire density with two minor exceptions; western larch switches positions with spruce, and Douglas-fir switches positions with lodgepole pine. The differences between the fire density values of the two cover types for both switched pairs was so slight, however, that the change in ranking is not significant. The ranking order of cover types within each of the five man-caused fire categories is also fairly consistent. This evidence suggests that some factor inherent in the cover type classification strongly affects the variability of fire density regardless of the firebrand.

Man-caused fire densities by cover type from Table 3.30 and fuel bulk

densities by cover type for four fuel strata from Table 3.2 were correlated to test for fuel bed effects on man-caused fire density. The natural logarithm transformations of grass, shrub, and litter fuel bulk densities accounted for over 85% of the variation in man-caused forest fire densities by cover type. The same three fuel parameters accounted for over 88% of the variation in lightning fire density. The high correlations and consistent ordering of cover types by fire density would lead to the inference that the fuel complex as identified by the cover type species exerts a strong influence over the probability that a given firebrand will cause a reportable fire. The fact that significant differences exist in absolute fire density between lightning and the five man-caused ignition sources reflects the influence of these activities, whether man or storm related, on the prevalence of firebrands. Simply stated, ignition source effects are manifested in the number of firebrands occurring in an area (or firebrand density), and cover type effects are manifested (via associated fuel bed properties) in the probability that any particular firebrand will start a reportable fire. These two factors translate into the well known components of fire risk and fire hazard, and would seem to adequately explain the variability in fire density in Tables 3.1 and 3.30.

3.4.3 Management Status Class and Man-Caused Fire Category Effects

Management status also showed a significant effect on fire density for each (and all) man-caused fire categories. Harvested/disposed sites had the highest man-caused forest fire density on the Lolo National Forest with 214 starts/mm acres/year, followed by harvested/undisposed sites with 135 starts, and standing timber sites with 5 starts annually per million acres (Table 3.31). The pattern between management status classes is not consistent for

TABLE 3.31

MAN-CAUSED FIRE DENSITY BY MANAGEMENT STATUS CLASS

LOLO NATIONAL FOREST : 1955 - 1974

MAN-CAUSED CATEGORY	STANDING TIMBER	HARVESTED/ UNDISPOSED	HARVESTED /DISPOSED	MAN-CAUSED CATEGORY AVER
Industrial - Right of Way	0.5 18	1.3 1	0 0	0.5 19
Forest Harv & Management	0.9 31	90.3 51	58.8 12	2.6 94
Recreational	2.5 86	4.9 10	112.5 27	3.4 123
Incendiary - Children	0.4 12	2.3 5	0 0	0.5 17
Miscellaneous Other	0.5 18	36.5 10	42.4 8	1.0 36
Mgmt Status Average	4.8 165	135.4 77	213.7 47	8.0 289

Fire Density (Starts/mm Acres/Year)
Fire Number (Total : 1955 - 1974)

all five categories of man-caused fires. Forest harvest and management activities, for example, had their highest fire density on harvested/undisposed sites. This is not expected since it is reasonable to assume a higher density of firebrands in undisposed slash areas for such activities than in other status classes. Similarly, a high degree of recreational use in undisposed slash units is not expected. Firebrand prevalence between management status classes obviously varies by the type of activity involved.

Even so, when all five man-caused fire categories are combined, harvested/disposed sites have the highest fire density. Just as was the case for lightning fire density by management status class and lightning and man-caused fire density by cover type, this suggests a strong influence by the fuel complex on the probability that a given firebrand will start a reportable fire. A compelling argument is offered by (1) the high correlation between fire density and fuel bulk density regardless of ignition source, (2) the high fire density of both man-caused and lightning fires on harvested/disposed sites, and (3) the dominance of fine, porous fuels on disposed sites on Northern Region national forests, that hazard reduction and site preparation methods commonly used on forest lands may actually increase the fire hazard of harvested sites.

3.4.4 Cover Type and Management Status Interactive Effects

Table 3.32 presents man-caused fire densities for all cause categories by cover type and management status class on the Lolo National Forest from 1955 to 1974. Since only 282 of the 409 man-caused fires were identifiable by both cover type and management status, the simultaneous two-way classification tended to spread the fire occurrence data too thinly for determination of any interactive effects or patterns on man-caused fire density. Only a

TABLE 3.32

MAN-CAUSED FIRE DENSITY BY COVER TYPE AND MANAGEMENT STATUS CLASS

LOLO NATIONAL FOREST : 1955 - 1974

COVER TYPE	STANDING TIMBER	HARVESTED/ UNDISPOSED	HARVESTED /DISPOSED	COVER TYPE AVERAGE
Ponderosa Pine	76.8 56	198.9 25	533.5 27	103.8 108
Western Larch	35.3 22	182.9 13	157.3 5	49.1 40
Engelmann - White Spruce	36.8 12	702.3 6	29.3 1	51.1 19
Western White Pine	0 0	384.6 1	0 0	22.8 1
Red Cedar - W. Hemlock	7.3 3	67.8 1	1639.3 2	14.1 6
Grand Fir	4.4 8	392.0 4	106.0 4	8.5 16
Douglas- fir	2.0 27	61.9 14	146.3 6	3.3 47
Lodgepole Pine	3.3 32	165.5 8	27.8 2	4.3 42
Subalpine Types	0.5 4	0 0	0 0	0.5 4
Mgmt Status Average	4.8 164	126.6 72	213.7 47	7.8 283

Fire Density (Starts/mm Acres/Year)
Fire Number (Total : 1955 - 1974)

generalized statement can be made that the pattern of man-caused fire density between cover type and management status classes resembled those found for lightning fires (Table 3.10).

3.4.5 Elevation and Man-Caused Fire Category Effects

Table 3.33 shows significant elevation effects on man-caused forest fire densities for all man-caused fire categories. Fire density was highest in the lowest elevation band, and steadily decreased with increasing elevation. The pattern is consistent for all man-caused fire categories on the Lolo National Forest.

3.4.6 Aspect and Man-Caused Fire Category Effects

Table 3.34 shows the significant aspect effects on all man-caused fire density categories on the Lolo National Forest. South aspects had the highest fire density for all man-caused fire categories, with southwest aspects the second highest. The only exception was forest management activity fire densities which were highest on southwest slopes and second highest on south aspects. Northeast and northwest aspects had the lowest man-caused fire densities for all activity categories.

3.4.7 Slope and Man-Caused Fire Category Effects

Slope steepness had a significant effect on fire densities for all classes of man-caused fires on the Lolo National Forest (Table 3.35). As was the case for lightning fires, densities started out high in the 0%-15% slope class, decreased steadily to about 45% slope, and then increased again as slope steepness increased. Man-caused fire density was 96 starts/mm acres/year on slopes under 16%, dropped to 3 starts/mm acres/year on 46%-55% slopes, and increased back to 97 starts/mm acres/year on slopes greater than 85%. The same pattern was followed for all categories of man-caused fires.

TABLE 3.33

MAN-CAUSED FIRE DENSITY BY ELEVATION

LOLO NATIONAL FOREST 1955 - 1974

ELEV (FT)	INDUSTRIAL RIGHT/WAY	FOREST MANAGEMENT	RECREATIONAL	INCENDIARY- CHILDREN	MISC.- OTHER	ELEV AVERAGE
.LT. 4000	11.8 39	3.0 10	26.4 87	8.8 29	9.1 30	59.1 195
4000- 4999	0.9 10	3.4 38	4.3 47	0.5 6	1.6 18	10.8 119
5000- 5999	0.2 3	2.5 40	1.2 20	0.1 1	0.2 3	4.2 67
6000- 6999	0.0 0	1.3 10	1.6 12	0.0 0	0.4 3	3.4 25
.GT. 7000	0.0 0	0.6 1	1.2 2	0.0 0	0.0 0	1.7 3
MAN-CAUSE AVERAGE	1.3 52	2.5 99	4.3 168	0.9 36	1.4 55	10.3 409

FIRE DENSITY FIRE NUMBER

TABLE 3.34

MAN-CAUSED FIRE DENSITY BY ASPECT

LOLO NATIONAL FOREST : 1955 - 1974

ASPECT	INDUSTRIAL RIGHT/WAY	FOREST MANAGEMENT	RECREATIONAL	INCENDIARY- CHILDREN	MISC.- OTHER	ASPECT AVERAGE
NORTH	1.0 5	1.2 6	3.1 15	0.3 1	0.6 3	6.2 30
N.EAST	0.7 3	0.9 4	2.1 9	0.0 0	0.7 3	4.4 19
EAST	0.2 1	1.9 9	2.8 13	0.6 3	0.2 1	5.7 27
S.EAST	0.2 1	2.6 16	2.3 14	0.5 3	0.7 4	6.2 38
SOUTH	4.4 20	4.8 22	6.6 30	2.2 10	3.7 17	21.6 99
S.WEST	0.3 1	6.1 18	5.1 15	1.4 4	1.4 4	14.3 42
WEST	0.8 3	3.4 13	3.4 13	1.0 4	1.8 7	10.4 40
N.WEST	0.0 0	1.1 8	0.7 5	0.1 1	0.1 1	2.1 15
LEVEL	15.7 18	2.6 3	47.1 54	8.7 10	12.2 14	86.4 99
MAN-CAUSE AVERAGE	1.3 52	2.5 99	4.3 168	0.9 36	1.5 54	10.3 409

FIRE DENSITY FIRE NUMBER

TABLE 3.35

MAN-CAUSED FIRE DENSITY BY SLOPE

LOLO NATIONAL FOREST : 1955 - 1974

SLOPE CLASS	INDUS- TRIAL	FOREST MGMT	RECREA- TIONAL	INCENDRY CHILDREN	MISCEL OTHER	SLOPE AVERAGE
0% - 15%	15.2 32	4.7 10	54.1 114	8.5 18	13.8 29	96.3 203
16% - 25%	1.2 4	3.2 11	4.1 14	1.5 5	0.9 3	10.8 37
26% - 35%	0.3 2	2.9 22	1.9 14	0.5 4	1.3 10	6.9 52
36% - 45%	0.7 6	1.3 11	1.4 12	0.1 1	0.6 5	4.0 35
46% - 55%	0.2 2	2.1 20	0.3 3	0.3 3	0.1 1	3.0 29
56% - 65%	0.2 1	3.3 18	1.3 7	0.6 3	0.7 4	6.1 33
66% - 75%	2.2 5	1.7 4	0.9 2	0.4 1	0.4 1	5.6 13
76% - 85%	0 0	0 0	4.5 1	4.5 1	0 0	9.0 2
85% +	0 0	58.1 3	19.4 1	0 0	19.4 1	96.8 5
Man-Caused Category Av	1.3 52	2.5 99	4.3 168	0.9 36	1.4 54	10.3 409

Fire Density (Starts/mm Acres/Year)
Fire Number (Total ; 1955 - 1974)

3.5 TACTICAL MAN-CAUSED FOREST FIRE DENSITIES

Table 3.36 shows the significant effect of the month of the year on all categories of man-caused forest fire densities on the Lolo National Forest. July is the month of highest fire density for every man-caused fire category, totaling 3.3 starts/mm acres/year for all causes. August was the second highest fire density class for every man-caused fire category, totaling 2.3 starts per million acres annually. Thirty-two percent of all man-caused fires started in July, and twenty-three percent started in August. This was just the opposite of lightning fires on the Lolo, which posed their greatest risk in August (49% of all lightning fires), followed by July (29%).

Table 3.37 breaks man-caused forest fire density into classes based upon the day of the week on which the fires started. While there is little day-of-the-week effect on total fire density for all man-caused fire categories, significant effects are evident within each fire cause class. Forty-six percent of industrial right-of-way fires occurred on Friday and Saturday, and forest management fires had their highest density on Monday, Tuesday, and Friday. Not unexpectedly, Saturday, Sunday, and Monday are the highest risk days from arsonists and children. Recreation related fires, on the other hand, appear fairly well distributed among all days of the week.

TABLE 3,36

MAN-CAUSED FIRE DENSITY BY MONTH

LOLO NATIONAL FOREST : 1955 - 1974

(Fires/mm Acres/Month)

MONTH	INDUSTRIAL RIGHT/WAY	FOREST MANAGEMENT	RECREATIONAL	INCENDIARY- CHILDREN	MISC.- OTHER	MONTHLY AVERAGE
JAN	0.0 0	0.0 0	0.0 1	0.0 0	0.0 0	0.0 1
FEB	0.0 0	0.0 1	0.0 0	0.0 0	0.0 0	0.0 1
MAR	0.0 1	0.0 0	0.0 0	0.0 0	0.0 0	0.0 1
APR	0.0 0	0.1 3	0.0 0	0.0 1	0.0 1	0.1 5
MAY	0.1 2	0.3 10	0.3 11	0.1 2	0.1 5	0.8 30
JUN	0.1 3	0.2 9	0.5 19	0.0 1	0.2 7	1.0 39
JUL	0.6 23	0.4 14	1.5 59	0.3 11	0.6 24	3.3 131
AUG	0.4 17	0.4 14	1.0 39	0.2 9	0.4 15	2.3 94
SEP	0.1 5	0.6 25	0.5 19	0.2 6	0.1 5	1.5 60
OCT	0.0 1	0.6 23	0.5 19	0.0 1	0.1 2	1.2 46
NOV	0.0 0	0.0 0	0.0 1	0.0 0	0.0 0	0.0 1
DEC	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0
MAN-CAUSE AVERAGE	1.3 52	2.5 99	4.2 168	0.8 31	1.5 59	10.3 409

FIRE DENSITY FIRE NUMBER

TABLE 3,37

MAN-CAUSED FIRE DENSITY BY DAY OF THE WEEK

LOLO NATIONAL FOREST : 1955 - 1974

DAY OF WEEK	INDUSTRIAL RIGHT/WAY	FOREST MANAGEMENT	RECREATIONAL	INCENDIARY- CHILDREN	MISC.- OTHER	DAY AVERAGE
SAT	0.3 12	0.2 8	0.6 25	0.2 9	0.1 4	1.4 58
SUN	0.1 3	0.2 9	0.8 30	0.2 6	0.2 9	1.5 57
MON	0.2 8	0.4 17	0.6 22	0.2 6	0.3 12	1.6 65
TUE	0.1 5	0.6 22	0.7 26	0.1 3	0.2 6	1.5 62
WED	0.2 8	0.3 11	0.6 24	0.1 5	0.2 7	1.4 55
THUR	0.1 4	0.4 15	0.6 22	0.1 3	0.2 9	1.4 53
FRI	0.3 12	0.4 17	0.5 19	0.1 4	0.2 7	1.5 59
MAN-CAUSE AVERAGE	1.3 52	2.5 99	4.2 168	0.8 31	1.5 59	10.3 409

FIRE DENSITY FIRE NUMBER

4.0 SUMMARY AND CONCLUSIONS

4.1 METHODOLOGY

An accurate, low cost methodology has been established for computation of lightning and man-caused forest fire densities on Northern Region national forests. Forest fire density expresses fire occurrence per unit area of some stand or site class per unit time. Examples are lightning fires per million acres of ponderosa pine cover type per year, and average annual man-caused fires per million acres of undisposed harvest slash. The computation of forest fire occurrence density requires fire occurrence data and corresponding estimates of forest acreage distributions stratified by common stand or site factor classes,

The methodology developed in the study used three separate data bases to make forest fire density computations. The original, uncoded Individual Fire Reports (5100-29 forms) were copied onto magnetic computer tape to serve as the fire occurrence data source. Each forest has its own set of 5100-29 forms on file, and a complete set for all forests is maintained at the Northern Region's Aviation and Fire Management office. The Forest Inventory/Stand Examination data base was accessed using the TABLES and OUTPUT programs of the FINSYS software system to estimate acreage distributions among cover type, elevation, aspect, slope, and other non-dynamic stand and site characteristics classes. The FINSYS software package resides on the USDA Forest Service's Fort Collins Computer Center UNIVAC 1100, and system documentation is available at the Northern Region's timber management office. Finally, the forest's Stand Examination and Management Status Record (FSH R1-2410-17) was used to determine the annual acreage distribution by cover type among management status classes of standing timber, harvested/undisposed, and harvested/disposed sites,

Section 3.1 details the six steps to follow when computing forest fire occurrence densities on Northern Region national forests. Briefly, they are:

- 1) problem design and stratification,
- 2) construction of a fire occurrence data tape,
- 3) estimation of acreages for non-dynamic stratification classes,
- 4) estimation of acreages for dynamic stratification classes,
- 5) computation of forest fire occurrence densities, and
- 6) analysis and interpretation of the fire density values.

Forest fire density estimates are perhaps of greatest value in comparing the relative fire risk and hazard of classes within the same stratification, or even classes between stratifications. For example, fire density facilitates direct comparison of ponderosa pine and Douglas-fir fire occurrence, or comparison between ponderosa pine occurrence and occurrence on southerly aspects, since all occurrence values are normalized by class acreages. Fire density should be especially useful in identifying those stand and site factors which most influence fire occurrence, and furthermore, should identify those classes within a particular stand or site characteristic that have the greatest relative fire occurrence. Such analysis and interpretation is not possible with fire occurrence data alone.

4.2 CONCLUSIONS

The following conclusions were drawn from the analysis of lightning and man-caused forest fire occurrence densities on the Lolo National Forest during the twenty year period from 1955 through 1974.

1) Fire occurrence density from all ignition sources totaled 48.5 fires/mm acres/year on the Lolo National Forest. Lightning fires posed the greatest risk with 38.2 fires/mm acres/year, and all man-caused fires had a total density of 10.3 fires/mm acres/year. Recreational activities were the source of greatest man-caused fire risk, 4.3 fires/mm acres/year, followed by timber harvest and forest and range management activities with 2.5 fires/mm acres/year.

2) Lightning fire risk was greatest in August with 20.3 fires/mm acres each month (49% of all lightning fires), followed by July with 12.1 fires/mm acres/month (29% of all lightning fires). Man-caused fire density, on the other hand, was greatest in July for all cause categories -- 32% of all man-caused fires occurred then for a density of 3.3 fires/mm acres/month. August was the second highest man-caused fire occurrence month with 23% of all man-caused fires, or 2.3 fires/mm acres/month.

3) Forest cover type had a highly significant effect on both lightning and man-caused forest fire densities. Ponderosa pine had the highest fire density of any cover type; 470 starts/mm acres/year for lightning fires, and 107 man-caused fires/mm acres/year. Table 4.1 shows the relative fire density indices by cover type for both lightning and man-caused fires, where ponderosa pine is assigned a maximum index value of 100.

4.1 RELATIVE FIRE DENSITY INDICES

BY COVER TYPE

LOLO NATIONAL FOREST : 1955 - 1974

<u>COVER TYPE</u>	<u>LIGHTNING FIRES</u>	<u>MAN-CAUSED FIRES</u>	<u>ALL FIRES</u>
Ponderosa Pine	100	100	100
Western Larch	35	48	39
Spruce	31	55	36
White Pine	29	21	28
Cedar/Hemlock	7	13	8
Grand Fir	5	8	6
Douglas-fir	5	3	5
Lodgepole Pine	5	4	5
Subalpine Types	4	1	3

4) Bulk density of the litter, grass and herb, and shrub fuel strata had a significant correlation with lightning and man-caused forest fire densities by cover type. The three fuel bed parameters together account for over 88% of the variation in lightning fire density, and over 85% of the variation in man-caused fire density by cover type.

5) The type of activity causing the fire, whether man or storm related, had a significant effect on absolute fire density, while fuel bed properties had a significant effect on fire density by cover type for each ignition source. The type of activity causing the ignition would therefore appear to determine the prevalence or density of firebrands in an area, while fuel bed and cover type characteristics affect the probability that a given firebrand will start a reportable fire. These two effects translate into the common components of fire risk and fire hazard, respectively.

6) Harvested stands that have received some form of hazard reduction or site preparation had higher lightning and man-caused fire densities than similar sites that had not been treated. Lightning fire density for harvested/disposed and harvested/undisposed stands were 585 and 106 starts /mm acres/ year, respectively. Similarly, man-caused fire density was 214 and 135 fires/ mm acres/ year on treated and untreated sites. Of the harvested areas on the Lolo National Forest that received hazard reduction or site preparation, over three-quarters were treated by prescribed burning, slash piling, or machine scarification methods that tend to increase exposed mineral soil and improve seedbed and growth conditions for fine live fuels. This fact, coupled with the high correlation between fuel bulk density and fire density, suggests hazard reduction and site preparation, as traditionally practiced on Northern Region national forests, may actually increase the fire hazard of harvested stands.

7) South and southwest aspects had the highest fire densities for both lightning and man-caused forest fires. Southerly aspects averaged 62 lightning and 19 man-caused fires/mm acres/year, while all other aspects averaged 32 and 8 fires/mm acres/year, respectively, for lightning and man-caused fires.

8) Both lightning and man-caused forest fire occurrence densities were highest for elevations under 4000 feet on the Lolo National Forest, and generally decreased with increasing elevation. Lightning fire density was also high for areas above 7000 feet.

9) For both lightning and man-caused fires, occurrence density was high on slopes under 16%, decreased as slope increased to about 45%, and then steadily increased again with increasing slope steepness.

4.3 FOOTNOTES

- 1/ Barrows, Jack S., David V. Sandberg, and John D. Hart. 1977. Lightning fires in Northern Rocky Mountain forests. Unpublished report on file at the Fire Meteorology R.W.U., Northern Forest Fire Lab, Missoula, Montana. 182 p.
- 2/ Stage, Albert R., and Jack R. Riley. 1972. An inventory design using stand examinations for planning and programming timber management. USDA Forest Service Intermountain Forest and Range Exp. Station. Research Paper INT-26. 17 p.
- 3/ SPSS, Statistical Packages for the Social Sciences. 1975. N. Nie, C.H. Hull, J.G. Jenkins, C. Steinbrenner, and D.H. Bent, eds. McGraw Hill Book Co., New York. 2nd edition.
- 4/ Kessell, Steven R. 1977. A gradient vegetation, resource, and fire management model for Glacier National Park, Montana. Unpublished doctoral dissertation. Cornell University, Ithaca, N.Y. 642 p.

TABLE 5.1 FIRE OCCURRENCE DATA TAPE FORMATS	Symbol	*Function		PROGRAM NAME	
	D	Duplicate		PROGRAM NUMBER	DATE
	P	Punch		MT 28836	12/77
	S	Skip		SOURCE DOCUMENT CARD FORM USED	
	V	Verify Left justify		Individual Fire Reports	
				PREPARED BY	PAGE 1 of 2
CARD FIELD	COLUMNS		NO.	FUNC.	REMARKS
	FROM	TO	COLS.	*	
Individual Fire Number	1	4	I4		
Forest Code	5	6	I2		
District Code	7	8	I2		
blank		9	b		
General Cause Category	10	11	I2		
Specific Cause Category	12	13	I2		
blank		14	b		
Year	15	16	I2		
Month	17	18	I2		
Day	19	20	I2		
blank		21	b		
Elevation	22	26	I5		
Aspect	27	28	I2		
Slope Percent	29	31	I3		
blank		32	b		
Cover Type (gen forest)	33	34	I2		
Stand Condition Class (M.P.)		35	I1		
blank		36	b		
Fire size Class		37	I1		
Acres Burned	38	44	F7.1		
blank		45	b		
Township Number	46	47	I2		

TABLE 5.2
FIRE OCCURRENCE TAPE CODES
Lolo National Forest: 1955- 1974

<u>Variable Name</u>	<u>Format</u>	<u>Code</u>
Individual Fire Number	I4	Consecutive numbering scheme for cross-reference by district
Forest Code	I2	16 Lolo
District Code	I2	01 Bonita 02 Missoula 03 Ninemile 04 Plains 05 Seeley Lake 06 Superior 07 Thompson Falls 08 St. Regis 09 Lolo
General Cause	I2	01 Lightning 02 Railroad 03 Incendiary 04 Children 05 Timber Harvest 06 Other Harvest 07 Forest and Range Management 08 Highway - Road 09 Power and Reclamation 10 Hunting and Fishing 11 Other Recreation 12 Miscellaneous / Other 13 Unknown
Specific Cause	I2	01 Lightning 02 Aircraft 03 Burning Vehicle 04 Exhaust - Powersaw 05 Exhaust - Other 06 Logging Line 07 Brakeshoe 08 Cooking Fire 09 Warming Fire 10 Smoking 11 Trash Burning 12 Field Burning 13 Land Clearing Burning/Meadow Burning 14 Slash Burning 15 R/W Burning 16 Resource Mgnt. Burning 17 Grudge Fire 18 Pyromania

TABLE 5.2 (continued)

<u>Variable Name</u>	<u>Format</u>	<u>Code</u>	
Specific Cause (continued)	I2	19	Smoking Out Bees or Game
		20	Insect or Snake Control
		21	Job Fire
		22	Blasting
		23	Burning Building
		24	Powerline
		25	Fireworks
		26	Playing with Matches
		27	Repeling Predatory Animals
		28	House or Stove Flue Sparks
		29	Other
		30	Equipment Use
		31	Debris Burning
Year	I2	Last Two Digits of Year	
Month	I2	01	January
		02	February
		03	March
		04	April
		05	May
		06	June
		07	July
		08	August
		09	September
		10	October
		11	November
		12	December
Day	I2	Two Digits - Actual	
Elevation	I5	Coded Directly Off Report Forms	
Aspect	I2	01	North
		02	Northeast
		03	East
		04	Southeast
		05	South
		06	Southwest
		07	West
		08	Northwest
		09	Ridgetop
		10	Flat
		11	Unknown
Slope	I3	Coded Directly Off Report Form in %	

TABLE 5.2 (continued)

<u>Variable Name</u>	<u>Format</u>	<u>Code</u>	
Cover Type	I2	01	Ponderosa Pine
		02	Douglas Fir
		03	Lodgepole
		04	Spruce
		05	Larch
		06	Grand Fir
		07	Western White Pine
		08	Cedar -- Hemlock
		10	Subalpine (subalpine fir, whitebark pine, limber pine)
		11	Coniferous Hardwoods (birch, green ash, cottonwood, aspen, other hardwoods)
		12	Juniper
		13	Pacific Yew
		14	Brush
		15	Grass / Weeds - Grass / Brush
		16	Unknown / Other
		17	Nonforested (NF2 and NF3)
Management Phase	I1	1	Seedling - Sapling
		2	Pole Timber
		3	Mature Uncut (+thinned)
		4	Mature Cut <u>with</u> Slash Disposal (resistance to control = low)
		5	Mature Cut <u>without</u> Slash Disposal (resistance to control = medium or high)
		6	Not Applicable / Unknown
		7	Grass / Brush - Sizeclass Unknown (1950's)
		8	Blowdown - Sizeclass Unknown (1950's)
		9	Bugkilled
Fire Size Class	I1	1	A
		2	B
		3	C
		4	D
		5	E+
Acres Burned	F6.1	Code as Actual Number of Acres Burned	
Township	I2	Actual	
Letter	I1	1	North
		2	South

TABLE 5.2 (continued)

<u>Variable Name</u>	<u>Format</u>	<u>Code</u>
Range	I2	Actual
Letter	I1	1 East 2 West
Section Number	I2	Actual
Ownership code	I2	01 Forest Service Origin 02 Other Origin
Land Class Designation	I2	01 Non-wilderness 02 Wilderness

TABLE 5.3

LIGHTNING FIRE OCCURRENCE
LOLO NATIONAL FOREST: 1955 - 1974

<u>FIRE YEAR</u>	<u>FOREST SERVICE NON-WILDERNESS</u>	<u>FOREST SERVICE WILDERNESS</u>	<u>STATE, PRIVATE & OTHER LANDS</u>	<u>TOTAL LIGHTNING</u>
1955	41	2	29	72
1956	65	0	47	112
1957	71	1	38	110
1958	34	0	39	73
1959	61	1	17	79
1960	85	3	21	109
1961	174	3	79	256
1962	61	2	29	92
1963	113	3	57	173
1964	29	0	27	56
1965	30	2	21	53
1966	84	0	53	137
1967	83	2	23	108
1968	41	1	14	56
1969	53	2	25	80
1970	101	0	39	140
1971	58	2	16	76
1972	74	0	48	122
1973	174	2	54	230
1974	81	0	37	118
Total	1513	26	713	2252

TABLE 5.4

MAN-CAUSED FIRE OCCURRENCE
LOLO NATIONAL FOREST : 1955 - 1974

<u>FIRE YEAR</u>	<u>FOREST SERVICE NON-WILDERNESS</u>	<u>FOREST SERVICE WILDERNESS</u>	<u>STATE, PRIVATE & OTHER LANDS</u>	<u>TOTAL MAN-CAUSED</u>
1955	8	0	20	28
1956	9	0	14	23
1957	10	0	39	39
1958	11	0	17	28
1959	12	0	27	39
1960	26	0	31	57
1961	17	0	41	58
1962	22	0	31	53
1963	17	0	19	36
1964	12	0	13	25
1965	3	0	11	14
1966	18	0	32	50
1967	23	0	85	108
1968	12	0	36	48
1969	24	0	73	97
1970	27	0	28	55
1971	27	0	15	42
1972	15	0	28	43
1973	68	0	53	121
1974	48	0	51	99
Total	409	0	654	1063